water

healthy aquatic
ecosystems

Overview of Fish Contaminant Monitoring Programs in Jurisdictions and Summary of Alberta Studies – Final Report

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OVERVIEW OF FISH CONTAMINANT MONITORING PROGRAMS IN JURISDICTIONS AND SUMMARY OF ALBERTA STUDIES

- FINAL REPORT -

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EXECUTIVE SUMMARY

The Government of Alberta is acting on one of the three overarching outcomes of the *Water for Life: Alberta's strategy for sustainability* (2003). This outcome - to assure "healthy aquatic ecosystems" in Alberta - requires province-wide monitoring and reporting programs to reflect the current and ongoing condition or "health" of aquatic ecosystems. One common indicator of ecosystem health is the measurement of bioaccumulation of contaminants in fish at the top of aquatic food webs. This information can also be used to develop human health advisories for the consumption of fish. Currently there is no provincial-scale monitoring program to routinely evaluate and report on the levels of contaminants in fish from the diverse aquatic ecosystems in Alberta.

Golder Associates Ltd. was contracted by the Alberta Environment to prepare an overview of monitoring programs for fish tissue contaminants and a summary of Alberta studies.

This report includes:

- Part I - an overview of major fish contaminant monitoring programs in Canada and seven national or major state programs in the United States of America (US).
- Part II - a summary of fish contaminant surveys and monitoring studies in Alberta. Note that the report does not include detailed analysis of contaminant data contained in the Alberta studies.
- Appendices include further details on the major fish contaminant monitoring programs and literature references for the monitoring programs and Alberta studies.

Part I Overview of major fish contaminant monitoring programs

Excluding studies confined to Alberta, a total of 18 ongoing and 16 completed Canadian monitoring programs were identified. The only nation-wide program is the Environmental Effects Monitoring (EEM) associated with the effects of pulp and paper mills and metal mine effluents. This sampling by industry is required under the Fisheries Act. Dioxins, furans and relevant metals are typically sampled in fish tissues as a component of the program. The Canadian government conducts monitoring across jurisdictions in the north. This monitoring involves programs which are ultimately concerned with the influences of fish contaminants on human health. Specifically, the data are used in fish consumption advisories[1]. These programs target contaminants such as mercury, other specific metals and persistent organic pollutants (POPs). Additional emerging contaminants of concern (which are usually persistent and bioaccumulative) have been added to the targeted contaminants list as information becomes available.

Another cross-jurisdictional monitoring program focuses on mercury in fish from Ontario, Quebec, Nova Scotia, Prince Edward Island, New Brunswick, Newfoundland and Labrador as part of the Conference of New England Governors and Eastern Canadian Premiers Mercury Monitoring Program

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[1] Consumption advisories for humans are typically issued by health or environment agencies to provide information on the quantity of fish from a waterbody which may be safely eaten (e.g., by adults, pregnant women and children).

(NEG-ECP), Mercury Action Plan. Within the provinces or territories, only Quebec and Ontario have ongoing province-wide fish contaminant monitoring. The Ontario program analyses fish for a wider range of contaminants than the Quebec program and both focus on data for the development of consumption advisories for humans. However, other programs, such as in the Great Lakes Monitoring Program, also include sampling of fish to assess ecosystem health.

In the US, there are three nation-wide monitoring programs resourced by the federal government: the National Water Quality Assessment Program (NAQWA), Biomonitoring of Environmental Status and Trends: Large River Monitoring Network (BEST:LRMN) and National Lake Fish Tissue Study (NLFTS). The main objective of the BEST program, the only long term initiative, is to examine nation-wide trends in fish contaminants including links to the ecosystem health of large rivers and tributaries. The NAQWA and NLFTS programs sample sport fish for human effects and bottom dwelling fish for ecosystem effects in streams and rivers or lakes and reservoirs, respectively. A fourth US federal program, the Great Lakes Fish Monitoring Program (GLFMP), began in the 1970s. In this program, fish data from the Great Lakes are used to develop human consumption advisories and to protect these aquatic ecosystems. This program is also linked to the Great Lakes Water Quality Agreement (GLWQA) between the US and Canadian jurisdictions. Most US states have state-wide fish tissue contaminant monitoring programs, primarily to evaluate influences on human health. The three state programs selected for this review (i.e., Iowa, Ohio and Washington) monitor a wide range of contaminants and compare the concentrations to guidelines or thresholds for human consumption and ecosystem health.

Part II Summary of fish contaminant studies in Alberta

Alberta fish tissue contaminant studies were summarized from 59 sources of information including study reports and data compilations. These sources included studies conducted from 1970 to 2005. Overall there was an increase in the total number of studies from the 1970s (5 reports), through the 1990s (28 reports), and up to 2005 (22 reports). Although most reports (34) were one-year studies, 24 covered several years, and some included longer-term compilations. Datasets over 20 years were a summary report of historic mercury data for Wabamun Lake, Northern River Basin Study reports (which included data since the 1970s) and a mercury dataset (1972-1989) supplied by Alberta Sustainable Resource Development.

Overall, fish tissue contaminant data are available from most watersheds (Figure 3.1, Table 3.2). Among the major river basins, most studies were for the Athabasca and South Saskatchewan river systems (total number of reports = 30 and 24, respectively). Lower number of studies were found for the North Saskatchewan and Peace river systems (total number of reports = 14 and 13, respectively). The high number of studies for the Athabasca River after the 1980s in particular, was related to increased efforts associated with several new or expanded pulp and paper mills, the Northern River Basins Study, and the follow-up Northern Rivers Ecosystem Initiative. Smaller numbers of studies were found for the Red Deer, Hay and Beaver River systems. No data were found for the Milk River, part of the Missouri/Mississippi river system.

Overall, the available information included fish contaminant data for 28 fish species collected since 1970. Most species were sport fish (18 species), comprising 11 coldwater species and 7 warm-water species. The most commonly studied fish species were northern pike and longnose sucker (38 and 37 reports, respectively). Of the remaining species, flathead chub, lake chub and longnose dace were the most frequently sampled (three or four reports each). Overall, based on the numbers of reports, there was a similar level of effort in flowing and standing-water habitats.

An examination of the monitoring effort for the contaminant types revealed that, in decreasing order, mercury, PCBs, other metals (i.e., selenium, arsenic, lead, and total metals), DDT, toxaphenes and PAHs were the most common contaminants examined. Using "report years" as a proxy of effort (i.e., the sum of the study durations for the relevant reports), there has been approximately four-fold more sampling for mercury than any other contaminant examined in Alberta. PCBs were the second most studied contaminant. Since 1970, there has been a general increase in the range of contaminants examined. Mercury was the only contaminant studied in the 1970s, and monitoring of PCBs, selected metals, DDT, toxaphenes, and dioxins and furans began in the 1980s. Overall the monitoring of trace organic contaminants has remained at a low intensity, while the sampling of metals has increased, especially in more recent years.

Overall, the guidelines used in the Alberta studies were primarily those used to address the consumption of fish by humans. The Health Canada (or Health and Welfare Canada) human consumption guidelines were used in 27 studies and the Canadian Food Inspection Agency (CFIA) guidelines were used in eight studies. USEPA guidelines were only used in four studies. Environment Canada, Ontario Ministry for the Environment, and CCME guidelines to protect wildlife or bird consumers of fish, or a small number of other guideline sources, were used in few studies. A total of 16 studies did not compare fish tissue contaminant concentrations with any type of guideline.

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GLOSSARY

General Symbols & Acronyms	Full Name
~	Approximately
+/-	plus or minus
<	less than
>	greater than
≤	less than or equal to
Σ	sum of
°C	degrees Celsius
µg/g	micrograms per gram
ng/g	nanograms per gram
µg/L	micrograms per litre
AB	Alberta
AEC	Alberta Environmental Centre, Vegreville (now ARC)
AENV	Alberta Environment
AMAP	Arctic Monitoring and Assessment Program
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
APHA	American Public Health Association
ARC	Alberta Research Council, Vegreville
ASRD	Alberta Sustainable Resource Development
BC	British Columbia
BC MOE	BC Ministry of Environment
BCMELP	BC Ministry of Environment, Lands and Parks
BEST	Biomonitoring of Environmental Status and Trends
CAEL	Canadian Association of Environmental Laboratories
CCME	Canadian Council of Ministers of the Environment
cd	compact disc
CFIA	Canadian Food Inspection Agency
cm	Centimetre
CRM	Certified Reference Material
d/s	Downstream
DFO	Department of Fisheries and Oceans
DIAND	Department of Indian Affairs and Northern Development
DL	detection limit
dw	dry weight
EC	Environment Canada
EIM	Environmental Information Management
EPA	Environmental Protection Agency
EQG	Environmental Quality Guidelines

GLOSSARY continued

General Symbols & Acronyms	Full Name
EROD	Ethoxyresorufin-O-deethylase
ETL	Enviro-test laboratory
FDA	Food and Drug Administration
FL	Florida
FWI	Freshwater Institute. Winnipeg
g	Grams
GLENDA	Great Lakes Environmental Database
GLFMP	Great Lakes Fish Monitoring Program
GLNPO	Great Lakes National Program Office
GLSFATF	Great Lakes Sport Fish Advisory Task Force
GLWQA	Great Lakes Water Quality Agreement
GNWT	Government of the Northwest Territories
HC	Health Canada
hrs	Hours
IDNR	Iowa Department of Natural Resources
IDPH	Iowa Department of Public Health
IJC	International Joint Commission
INAC	Indian and Northern Affairs Canada
Inc.	Incorporated
kg/year	kilograms per year
km	Kilometres
LC50	lethal concentration that kills 50% of test organisms
LRMN	Large River Monitoring Network
Ltd	Limited
MB	Manitoba
mg	Milligrams
mg/kg	milligram per kilogram
mg/L	milligrams per litre
mL	Millilitre
mm	Millimetres
N/A	not available
NAE	National Academy of Engineering
NAQWA	National Water Quality Assessment
NAS	National Academy of Science
NASQAN	National Stream Quality Accounting Network
NB	New Brunswick
NCBP	National Contaminant Biomonitoring Program
NCP	Northern Contaminants Program
NEI	Northern Ecosystems Initiative

GLOSSARY continued

General Symbols & Acronyms	Full Name
NFLD	Newfoundland
ng/g	nanograms per gram
NLET	National Laboratory for Environmental Testing
NLFTS	National Lake Fish Tissue Study
NRBS	Northern River Basins Study
NRC	National Research Council
NREI	Northern Rivers Ecosystem Initiative
NSR	North Saskatchewan River
NTR	National Toxics Rule
NU	Nunavut
NWRI	National Water Research Institute
NWT	Northwest Territories
NYSDEC	New York State Department of Environmental Conservation
ODNR	Ohio Department of Natural Resources
OH	Ohio
OMOE	Ontario Ministry of Environment
ON	Ontario
oz	Ounce
pg/g	picograms per gram
pg/mL	picograms per millilitre
ppm	parts per million
ppt	parts per trillion
QA	Quality Assurance
QC	Quality Control
QC	Quebec
RAFT	Regional Ambient Fish Tissue Monitoring Program
RAMP	Regional Aquatics Monitoring Program
SD	standard Deviation
SE	Standard Error
SERM	Saskatchewan Environment and Resource Management
SETAC	Society of Environmental Toxicology and Chemistry
SK	Saskatchewan
SRC	Saskatchewan Research Council
SV	Screening Value
TDI	Tolerable daily intake
TEQ	toxic equivalents
TOC	Total Organic Carbon
TRC	Tissue Residue Criterion
TSS	Total Suspended Sediment

GLOSSARY continued

General Symbols & Acronyms	Full Name
US	United States
US-EPA	United States Environmental Protection Agency
US-FDA	United States Food and Drug Agency
USGS-BRD	United States Geological Survey - Biological Resources Division
vol	Volume
WSTMP	Washington State Toxics Monitoring Program
ww	wet weight
YK	Yukon

LIST OF ACRONYMS IN ANALYTICAL CHEMISTRY

Abbreviation	Full Name
AAS	atomic absorption spectrophotometry
AES	atomic emission spectroscopy
CVAAS	cold vapour atomic absorption spectroscopy
CVAES	cold vapour atomic emission spectroscopy
CVAFS	cold vapour atomic fluorescence spectrophotometry
DFAAS	direct flame atomic absorption spectrophotometry
GC	gas chromatography
GC/ECD	gas chromatography with electron capture detection
GC/MS	gas chromatography with mass spectrometry
GC/MSD	gas chromatography with mass selective detector
GC/MS-SIM	gas chromatography with mass spectrometry selective ion monitoring
GC-ECNIMS	gas chromatography with electron capture negative ion mass spectrometry
GFAAS	graphite furnace atomic absorption spectrophotometry
GFAES	graphite furnace atomic emission spectrometer
HGAAS	hydride generation atomic absorption spectrophotometry
HPLC	high pressure liquid chromatography
HVAAS	hydride vapour atomic absorption spectrophotometry
ICAP	induction-coupled argon plasma
ICAP-AES	induction-coupled argon plasma atomic emission spectroscopy
ICP	inductively coupled plasma
ICP-AES	inductively coupled plasma atomic emission spectroscopy
ICP-MS	inductively coupled plasma mass spectrometry
MS	mass spectrometry

LIST OF FISH SPECIES CODES

Code	Common Name	Scientific Name
ALEW	Alewife	*Alosa pseudoharengus*
AMEL	American Eel	*Anguilla rostrata*
ARCH	Arctic Char	*Salvelinus alpinus alpinus*
ARCS	Arctic Cisco	*Coregonus autumnalis*
ARGR	Arctic Grayling	*Thymallus arcticus arcticus*
ATHL	Atlantic Halibut	*Hippoglossus hippoglossus*
ATSL	Atlantic Salmon	*Salmo salar*
ATST	Atlantic Sturgeon	*Acipenser oxyrinchus oxyrinchus*
ATTM	Atlantic Tomcod	*Microgadus tomcod*
BGBF	Bigmouth Buffalo	*Ictiobus cyprinellus*
BKTR	Brook Trout	*Salvelinus fontinalis*
BLCR	Black Crappie	*Pomoxis nigromaculatus*
BLTR	Bull Trout	*Salvelinus confluentus*
BLUE	Bluegill	*Lepomis machrochirus*
BLCT	Blue catfish	*Ictalurus furcatus*
BNTR	Brown Trout	*Salmo trutta trutta*
BOWF	Bowfin	*Amia calva*
BRBL	Brown Bullhead	*Ameiurus nebulosus*
BRWH	Broad Whitefish	*Coregonus nasus*
BURB	Burbot	*Lota lota*
CARP	Common Carp	*Cyprinus carpio*
CHCT	Channel Catfish	*Ictalurus punctatus*
CHPC	Chain Pickerel	*Esox niger*
CISC	Cisco	*Coregonus artedi*
CMSL	Chum Salmon	*Oncorhynchus keta*
CNSL	Chinook Salmon	*Oncorhynchus tshawytscha*
COSL	Coho Salmon	*Oncorhynchus kisutch*
CTTR	Cutthroat Trout	*Oncorhynchus clarkii clarkii*
DLVR	Dolly Varden Char	*Salvelinus malma malma*
FALL	Fallfish	*Semotilus corporalis*
FLCH	Flathead Chub	*Hybopsis gracilis*
FRDR	Freshwater Drum	*Aplodinotus grunniens*
FRSC	Fourhorn Sculpin	*Triglopsis quadricornis*
GOLD	Goldeye	*Hiodon alosoides*
GRCD	Greenland Cod	*Gadus ogac*
GRTR	Greenland Turbot	*Reinhardtius hippoglossoides*
GZSH	Gizzard Shad	*Dorosoma cepedianum*
HSCS	Hoy's cisco	*Coregonus hoyi*

LIST OF FISH SPECIES CODES continued

Code	Common Name	Scientific Name
INCO	Inconnu	*Stenodus leucichthys*
KKSL	Kokanee Salmon	*Oncorhynchus nerka*
LRSC	Largescale Sucker	*Catostomus macrocheilus*
LKCH	Lake Chub	*Couesius plumbeus*
LKST	Lake Sturgeon	*Acipenser fulvescens*
LKTR	Lake Trout	*Salvelinus namaycush*
LKWH	Lake Whitefish	*Coregonus clupeaformis*
LRBS	Largemouth Bass	*Micropterus salmoides*
LNDC	Longnose Dace	*Rhinichthys cataractae*
LNSC	Longnose Sucker	*Catostomus catostomus*
LSCS	Least Cisco	*Coregonus sardinella*
MNWH	Mountain Whitefish	*Prosopium williamsoni*
MOON	Mooneye	*Hiodon tergisus*
MUSK	Muskellunge	*Esox masquinongy*
NRPK	Northern Pike	*Esox lucius*
NRPM	Northern Pikeminnow	*Ptychocheilus oregonensis*
NRWH	Northern Whitefish	*Coregonus peled*
OCPR	Ocean Perch	*Sebastes alutus*
PCHR	Pacific Herring	*Clupea pallasii pallasii*
PMCH	Peamouth Chub	*Mylocheilus caurinus*
PNSL	Pink Salmon	*Oncorhynchus gorbuscha*
PRDC	Pearl Dace	*Semotilus margarita*
PUMP	Pumpkinseed/common sunfish	*Lepomis gibbosus*
QUIL	Quillback	*Carpiodes cyprinus*
RCBS	Rock Bass	*Ambloplites rupestris*
RNSM	Rainbow Smelt	*Osmerus mordax*
RNTR	Rainbow Trout	*Oncorhynchus mykiss*
RNWH	Round Whitefish	*Prosopium cylindraceum*
SAUG	Sauger	*Sander canadense*
SCSL	Sockeye Salmon	*Oncorhynchus nerka*
SETR	Sea Trout	*Salvelinus fontinalis*
SHRD	Shorthead Redhorse Sucker	*Moxostroma macrolepidotum*
SISC	Siscowet	*Salvelinus namaycush siscowet*
SLRD	Silver Redhorse	*Moxostoma anisurum*
SLSC	Slimy Sculpin	*Cottus cognatus*
SMBS	Smallmouth Bass	*Micropterus dolomieui*
SPLA	Splake	*Hybrid of Salvelinus namaycush (Walbaum) and Salvelinus fontinalis (Mitchill)*
STFL	Starry Flounder	*Platichthys stellatus*
STSH	Spottail Shiner	*Notropis hudsonius*

LIST OF FISH SPECIES CODES continued

Code	Common Name	Scientific Name
TRPR	Trout Perch	*Percopsis omiscomaycus*
WALL	Walleye	*Sander vitreum*
WHBS	White Bass	*Morone chrysops*
WHCR	White Crappie	*Pomoxis annularis*
WHPR	White Perch	*Morone americana*
WHSC	White Sucker	*Catostomus commersoni*
YLBL	Yellow Bullhead	*Ameiurus natalis*
YLPR	Yellow Perch	*Perca flavescens*

LIST OF CHEMICAL ABBREVIATIONS

Abbreviation	Full Name
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4-D	2,4-dichlorophenoxyacetic acid
APE	alkylphenol ethoxylates
BDPE	bromodiphenyl ether
BFR	brominated flame retardant
BTBPE	1,2-bis(2,4,6-tribromophenoxy)ethane
CBz	Chlorobenzene
CDD	chlorodibenzo-p-dioxin
CDF	chlorodibenzo-p-furan
CDPE	clorodiphenyl ether
CHB	Chlorobornanes
CHL	Chlordane
CP	Chlorophenolics
DBDPE	decabromodiphenyl ethane
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichloro-diphenyl-trichloroethane
EPN	0-ethyl, 0-4-nitro-phenyl phenyl phosphono-thiolate
FTCA	fluorotelomer carboxylic acids
FTUCA	fluorotelomer unsaturated carboxylic acids
HBCD	hexabromocyclododecane
HCB	Hexachlorobenzene
HCH (BHC)	Hexachlorocyclohexane
MCPA	2-methyl-4-chlorophenoxyacetic acid
MCPB	2-methyl-4-chlorophenoxy)butyric acid
MEO-DDE	2,2-bis (p-methoxyphenyl)-1, 1-dichloroethylene
MEO-DDT	Methoxychlor
OC	Organochlorine
OCDD	octachlorodibenzo-p-dioxin
PAH	polyaromatic hydrocarbon
PANH	Polyanhydride
PBB	polybrominated biphenyls
PBDE	polybrominated diphenyl ether
PBT	persistent bioaccumulative toxin
PCA	polychlorinated-n- alkane
PCB	polychlorinated biphenyl
PCDD/F	polychlorinated dibenzo-p-dioxins and furans
PCN	polychlorinated naphthalenes
PCNB	Pentachloronitrobenzene
PFCA	Perfluorocarboxylic acids
PFO	perfluorinated compounds
PFOS	perfluorooctane sulfonate
POP	Persistent Organic Pollutant
RA	Resin acid

LIST OF CHEMICAL ABBREVIATIONS continued

Abbreviation	Full Name
RFA	resin fatty acids
TCDD	tetrachlorodibenzo-p-dioxin
TCDF	tetrachlorodibenzo-p-furan
TCNB	Tetrachloronitrobenzene
TCNB	Tetrachloronitrobenzene
TCP	Trichlorophenol
γ-HCH	Lindane
Ag	Silver
Al	Aluminium
As	Arsenic
B	Boron
Ba	Barium
Be	Beryllium
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	Iron
Hg	Mercury
K	Potassium
Li	Lithium
MeHg	Methyl-mercury
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
Ni	Nickel
P	Phosphorous
Pb	Lead
Sb	Antimony
Se	Selenium
Si	Silicon
Sn	Tin
Sr	Strontium
Ti	Titanium
Tl	Thallium
U	Uranium
V	Vanadium
Zn	Zinc
Zr	Zirconium

1 GENERAL INTRODUCTION

The Government of Alberta is acting on one of the three main outcomes of the *Water for Life: Alberta's strategy for sustainability* (2003): to assure "healthy aquatic ecosystems" in Alberta. This requires province-wide monitoring and reporting programs to reflect the current and ongoing condition or "health" of aquatic ecosystems. Routine evaluation of the status of provincial sport fish populations by Alberta Sustainable Resource Development (ASRD) and partners can be used to support this need. Other complimentary measures of fisheries condition can also be used to determine the health of aquatic ecosystems. One common indicator is the measurement of the bioaccumulation of contaminants in fish at the top of food webs in aquatic ecosystems. These data, which typically include sport fish species, usually reflect long-term exposure and bioaccumulation of contaminants (especially persistent chemicals) from point source effluents or more diffuse (non-point) sources. Non-point sources include contaminants in air deposition and runoff influenced by land-use activities. Certain fish contaminant data are also used to determine fish consumption advisories for humans.

The range of environmental contaminants is continuously increasing, and in many cases, there is limited knowledge on their effects in aquatic ecosystems. The contaminants originate from a variety of sources, such as treated municipal and industrial wastewaters, agricultural run-off, and long-range transport and deposition of air pollutants. Currently there is no provincial-scale monitoring program in Alberta to routinely report on the levels of contaminants in fish. Along with available historical data, a comprehensive (new) provincial monitoring program could be used to determine current (baseline) conditions, trends over time, fate and potential effects of contaminants in aquatic ecosystems, as well as fish consumption advisories for humans.

Golder Associates Ltd. was contracted by the Alberta Environment to carry out an overview of monitoring programs for fish tissue contaminants and a summary of Alberta studies. These are presented in the report as follows:

- Part I – comprises two components: 1) an overview of past and current major fish tissue contaminant monitoring programs in Canada (excluding Alberta-specific studies), and 2) an overview of US federal programs and three US state monitoring programs. The US programs were selected for their comprehensiveness, availability of information to the public, and inclusion of ecosystem health in the monitoring program objectives.

- Part II – is an inventory of Alberta fish tissue contaminant studies and limited data which were available for this contract. General summaries of information in the studies are presented as monitoring effort over time, among major river basins (or watersheds), by fish species in flowing and standing waters, and by contaminant type. Note that that these summaries do not include a detailed analysis of contaminant data contained in the Alberta studies.

Appendices include further details on the major fish contaminant monitoring programs, and literature references for the monitoring programs and Alberta studies.

Time and resource constraints meant that the information obtained and presented for this project is not exhaustive. The acquisition of information depended heavily on the responsiveness of monitoring program contacts, availability of the data/reports, and in some cases, permission to use the reports.

2 PART I: OVERVIEW OF MAJOR FISH CONTAMINANT PROGRAMS

The objectives of Part I were to provide:

1) an overview of major, recent and ongoing, fish tissue contaminant monitoring programs in Canada (excluding Alberta-specific programs); and

2) an overview of US federal monitoring programs for fish tissue contaminants and three US state monitoring programs selected for their comprehensiveness, public availability and inclusion of ecosystem health in the monitoring objectives.

The Canadian fish tissue contaminant monitoring programs were identified by:

- contacting the relevant authorities in each province/territory;
- following up on contacts suggested by AENV; and,
- internet searches for fish contaminant studies in Canada.

The US monitoring review is limited to seven of the most intensive programs that are well documented and readily available. The programs were located using internet searches and contacting project managers from relevant government departments. Four federal monitoring programs, as well as three state-wide programs from Iowa, Ohio and Washington State are summarized here. Many of the American states have intensive, large-scale fish contaminant monitoring programs, but only a few have the studies presented in a detailed and comprehensive report format. The three state monitoring programs were selected because they included different monitoring approaches and monitoring to evaluate environmental and human health.

Limited internet searches on fish tissue contaminant programs in other countries with recognized experience and expertise in aquatic monitoring revealed that, in Europe, only Norway, Finland, Sweden, Denmark, Netherlands and Belgium have established nation-wide fish contaminant monitoring programs in fresh waters. Of these programs, only the Swedish studies were readily available; however, the range of contaminants sampled was no greater than the selected US monitoring programs. In addition, no effects thresholds/benchmarks were used in the Swedish study to evaluate impacts of contaminants on environmental health. Australia, where a lot of effort is put into the monitoring of freshwater ecosystems, there are no federal or state-wide monitoring programs for contaminants in freshwater fishes.

2.1 MONITORING PROGRAMS IN CANADA

An overview of the main fish tissue contaminant monitoring programs in Canada is provided here. Canadian fish tissue contaminant monitoring studies are organized according to whether they are ongoing (Table 2.1) or completed (Table 2.2).

A total of 18 ongoing, and 16 completed, Canadian monitoring studies are summarized:

- Details of each program are summarised using consistent headings in the text and further details are in Appendix 1. The headings include: years of data; overall objectives; number of sampling sites; reasons for choosing sampling locations; contaminants; effects thresholds; fish species; type of tissue sample; and other categories. The summary matrix can be used to compare the monitoring programs.

In Canada, the fish contaminant monitoring programs range from cross-jurisdictional, federal or provincial government programs, and smaller scale monitoring studies conducted by provincial and territorial governments. The programs vary widely in terms of spatial coverage, range of contaminant analyses, and duration in years.

The concentrations of contaminants in fish tissues can be compared to science-based or other suitable effects thresholds and guideline concentrations to evaluate potential implications to environmental and human health. However, the number and availability of suitable guidelines is limited. For example, most Canadian guidelines are developed to assess the consumption of fish by humans or wildlife and they are limited to a relatively small number of contaminants (see Section 2.1.3).

Table 2.1 Ongoing Canadian fish tissue contaminant monitoring programs, excluding studies confined to Alberta*

Geographic Region	Monitoring Program	Proponent	Program Initiation
Canada-wide	Environmental Effects Monitoring Program: Pulp and Paper, and Metal Mining	EC, DFO, Industry	1992
PE, NS, NB, NL, QC	Conference of New England Governors and Eastern Canadian Premiers Mercury Monitoring Program	Can. Prov. Gov. of PE, NS, NB, NL, QC; and US State Gov. of CT, MA, ME, NH, RI, VT	1976
QC	Metal Concentrations in Fish and Sediments from Lakes aux Dorés, Chibougamau, Obatogamau and Waconichi	QC MDDEP	1998
	Quebec Sportfish Monitoring Program	QC MDDEP	1978
	St. Lawrence Action Plan/St. Lawrence Vision 2000	EC	1975, 1989
NU	Spatial and Temporal Trends of Mercury and Other Metals in Landlocked Char from Lakes in the Canadian Arctic Archipelago	EC, INAC, NCP, AMAP	1992
ON	Ontario Sportfish Monitoring Program	ON MOE, ON MNR	1970
	Great Lakes Monitoring Program	ON MOE, DFO, EC	1977
	Great Lakes Monitoring Program: Contaminants in Young-of-the-Year Spottail Shiners	ON MOE	1976
SK	Athabasca Working Group Environmental Monitoring Program	SERM, Industry, Community	2000
	Mercury in Saskatchewan Fish: Guidelines for Consumption	SERM	1968
NT	An Investigation of Factors Affecting High Mercury Concentrations in Predatory Fish in the Mackenzie River Basin	EC, AMAP	1999
	Spatial and Long-term Trends in Organic Contaminants and Metals in Fish Species Important to the Commercial, Sports, and Domestic Fisheries of Great Slave Lake and the Slave River Ecosystem	EC, AMAP	1999
	Spatial and Long-term Trends in Persistent Organic Contaminants and Metals in Lake Trout and Burbot in Great Slave Lake, NT	INAC, NCP	1999
	Spatial and Long-term Trends in Persistent Organic Contaminants and Metals in Temporal Trends Studies of Heavy Metals and Halogenated Organic Contaminants including New and Emerging Persistent Compounds, in Mackenzie River Burbot, Fort Good Hope, NWT	DFO, NCP	1999
YT	Monitoring Yukon Fish as Traditional Foods	DFO, INAC, NCP	1992
	Organochlorine contaminants in three Yukon Lakes: focus on Lake Laberge	DFO, INAC, NCP	1992
BC	Selenium Monitoring in Sculpins	BC MOE, Coal Industry	1998

* Part II deals specifically with Alberta studies.

Table 2.2 Previous Canadian fish tissue contaminant monitoring programs, excluding studies confined to Alberta*

Geographic Region	Program	Proponent	Program Duration
Canada-Wide	Dioxin and Furan Monitoring Program	Health and Welfare, EC, DFO, Provincial Governments	1987-1988
NT, YT, NU, NL	A History of Total Mercury in Edible Muscle of Fish from Lakes in Northern Canada	DFO	1971-2001
MB	Manitoba Biomonitoring Program	MB DOE	1978-1992
	Mercury Monitoring Agreement, Northern Flood Agreement	MB DNR	1983-1989
SK	Biological Survey of the North Saskatchewan River	SERM	1985-1986
	Mercury in Fish from Northern Saskatchewan	SK Resources Branch	1969-1976
NT	Slave River Environmental Quality Monitoring Program	DIAND, GNWT, DFO, EC	1990-1995
	Liard River Environmental Quality Monitoring Program	DIAND, GNWT, DFO, EC	1992-1995
	A Limnological Study of Selected Lakes in the Lac de Gras area, Northwest Territories	DFO, DIAND	1994
	Northern Water Resource Studies	DIAND, DFO	1988-1990
AB, NT, SK	Mercury Concentrations in Fish in Lakes in the Mackenzie River Basin	EC, NCP, NEI, DFO	1996-2000
AB, NT	Northern River Basins Study	EC, AENV, GNWT	1992-1994
	Northern Rivers Ecosystem Initiative	EC, AENV, GNWT	1998-2003
YT	Organochlorines in Yukon Fish	INAC, NCP	1992-1997 (may be ongoing under different name)
BC	Metal concentrations in fish tissue from uncontaminated BC lakes	BC MOE	1982-1987
	Persistent Organohalogen Contaminants in Fish from Lakes and Reservoirs in Southwestern British Columbia, Canada	EC	1999-2002
	Fraser River Action Plan: Resident Fish Contaminant and Health Assessment	EC, DFO	1994-1996

* Part II deals specifically with Alberta studies.

2.1.1 Jurisdiction and geographic distribution of programs

Federal programs

In Canada, pulp and paper mills are required to conduct environmental effects monitoring (EEM) under the Pulp and Paper Effluent Regulations of the Fisheries Act. The initial stages of the EEM program typically included the sampling of fish tissues for dioxins and furans. This program started in 1992 and involves sampling effluent impacted sites and unimpacted or reference sites. The monitoring data are stored in an Environment Canada searchable (internet) database: the National EEM Database for Pulp and Paper. Another component of the EEM program, under the federal Metal Mining Effluent Regulations, was initiated in 2003/2004. This also requires metal mines to monitor fish tissue contaminant monitoring and the data are stored in the National EEM Database for Metal Mining.

The federal government currently conducts contaminant monitoring programs in the Canadian north. Programs for monitoring traditional/country foods in the Yukon, and monitoring of mercury and persistent organic pollutants in landlocked Arctic char in Nunavut began in 1992. In the Northwest Territories, persistent organic pollutants and metals have been monitored in fish from the Mackenzie River Basin, Great Slave Lake and Slave River under several programs conducted by the federal government. These programs were funded by the Northern Contaminants program and the Arctic Monitoring and Assessment Programs. The studies began in 1999, sample fish annually, and also incorporate emerging chemicals of concern.

The Canadian government has also conducted several shorter term monitoring programs in British Columbia, Nunavut, Northwest Territories and Yukon to determine the level of contaminants, including metals and persistent organic pollutants at various reference and impacted sites. The federal government has also conducted a short-term monitoring program to investigate dioxin and furan contamination in fish near pulp and paper mills in British Columbia, Alberta, Saskatchewan and New Brunswick. All of these programs were conducted for up to 6 years and completed before the year 2000.

Province/Territory-wide programs

An inter-provincial group of eastern Canadian provinces made up of Ontario, Quebec, Nova Scotia, Prince Edward Island, New Brunswick, Newfoundland and Labrador participate in an ongoing fish contaminant monitoring programs. It is a joint Canadian:US program under the Conference of New England Governors and Eastern Canadian Premiers (NEG-ECP) Mercury Monitoring and Action Plan. Details of this program are not available at this time.

Quebec conducts a large sport fish contaminant monitoring program which evaluates the concentrations of mercury and persistent organic pollutants on a provincial scale. Another long-term monitoring program is used to assess metals, PCBs, dioxins and furans in lakes influenced by mining activities.

The most comprehensive Canadian fish contaminant monitoring program is the Ontario Sportfish Monitoring Program. This ongoing program begun in 1970, samples fish annually, though not from all of the lakes in the program. Fish tissues are analyzed for wide range of metals, and persistent organic pollutants (i.e. organochlorines, pesticides, and hydrocarbons). The program adds emerging chemicals of concern (e.g. flame retardants) as information and analytical techniques become available. In addition, Ontario participates in the Great Lakes Fish Monitoring Program in cooperation with the federal government and the United States government. This program monitors an extensive list of organic and inorganic contaminants.

Currently, British Columbia, Alberta, Saskatchewan, Manitoba, Nunavut, Northwest Territories and Yukon do not have province- or territory-wide freshwater fish tissue monitoring programs. However, they do have smaller-scale and usually short-term monitoring studies.

Smaller-scale and older monitoring programs

Saskatchewan and Manitoba have had provincial mercury monitoring programs in the past (Table 2.2). Manitoba's program was conducted annually from 1978 to 1992, with additional sampling conducted in 2003. Saskatchewan's program began in 1968 and is likely to continue following a recent lapse in sample collections. In northern Saskatchewan, in response to environmental and human health concerns near uranium mines, the provincial government, the uranium mines and local communities created a working group to monitor changes in environmental health. This program started in 2000, is ongoing, and includes monitoring of metals, trace elements and radionuclides fish tissue contaminants.

In British Columbia, the provincial government monitoring is focused on short-term monitoring of metals in uncontaminated lakes and an investigation of selenium bioaccumulation in fish near coal mines.

2.1.2 Contaminants investigated

The major Canadian monitoring programs, such as the Ontario Sportfish Monitoring Program, the Great Lakes Monitoring Program and several of the Arctic monitoring programs, assess a variety of metals, organochlorines, PCBs, polychlorinated dibenzofurans and dibenzodioxins, PAHs, chlorophenols, pesticides (i.e., toxaphene, mirex, and DDT), brominated flame retardants, PBDEs and other emerging chemicals of concern.

Seven of the monitoring programs dealt exclusively with mercury contamination of fish tissues. In one program, fish tissues are analyzed solely for dioxins and furans and another one specifically deals with the bioaccumulation of selenium in fish.

2.1.3 Human *versus* environmental health guidelines

Most of the programs conducted in Canada are primarily to evaluate human health concerns, and as such, compare the fish contaminant levels to the Health Canada human consumption guidelines. The most common comparison is with the mercury guidelines, 0.5 µg/g ww (wet weight) for commercial fisheries, and 0.2 µg/g ww for subsistence fisheries. Other guidelines used in a number of studies include the US-EPA toxaphene guideline for the protection of human health and Health Canada guidelines for PCBs, organochlorines (OCs), dioxins and furans, lead, arsenic, HCHs, chlordanes, DDT, heptachlor, endrin, toxaphene, mirex and photomirex.

In one BC monitoring study, fish health was also considered, where the tissue selenium concentrations were compared to thresholds for effects on fish, i.e., the BC Interim whole body guideline and the draft US-EPA whole body criterion.

Other guidelines used in the Canadian programs are the CCME tissue residue guidelines for the protection of wildlife, or in some cases bird consumers of aquatic biota (i.e., for methyl-mercury, PCBs, dioxins, furans, DDT, and toxaphene), the International Joint Commission guidelines for the protection of wildlife (toxaphene and DDT), the BC criteria for fish tainting (chlorophenols), and the US-EPA guidelines for the protection wildlife (mercury, PCBs, dioxins and furans).

The Slave River Monitoring program, the Ontario Sportfish Monitoring Program and the Great Lakes Monitoring Program are the three largest Canadian fish contaminant monitoring programs in terms of number of contaminants investigated and in using the most comprehensive list of protection guidelines for humans and wildlife.

2.2 MONITORING PROGRAMS IN THE US

Summaries of the seven US programs reviewed are presented in Appendix 2.

2.2.1 Federal Programs

The US monitoring programs are particularly well established at the federal level lead by the US Environmental Protection Agency (US EPA) or US Geological Survey (USGS). There are four federal programs that include fish tissue contaminant monitoring:

- Great Lakes Fish Monitoring Program (GLFMP);
- National Lake Fish Tissue Study (NLFTS);
- National Water Quality Assessment Program (NAQWA); and
- Biomonitoring of Environmental Status and Trends: Large River Monitoring Network (BEST: LRMN).

The GLFMP and BEST: LRMN have near–continuous data for fish tissue contaminants beginning in the 1960s. Earlier data are from preceding programs such as the National Contaminant Biomonitoring Program (NCBP). This program evolved from the BEST: LRMN. The NLFTS comprised a 5 year intensive survey of lake fishes throughout the US. This program was completed in 2005, although archived fish tissue samples are currently being analyzed for emerging contaminants. The NAQWA monitors streams and rivers throughout the US. The program's main fish tissue contaminant sampling effort occurred between 1992 and 2001, involving about 45 Study Units each corresponding to a major hydrologic basin (and covering parts of every mainland US state). Currently, only a few NAWQA study units are continuing for fish tissue sampling. In most of the NAWQA study units, the fish contaminant component was treated as discrete 1 to 5 year surveys. All of the above four programs followed precise field and laboratory methods described in agency reports, which are available over the internet. The BEST: LRMN program is exceptional in that it also includes the use of biomarkers, histopathology, somatic indices, as well as concentrations of contaminants in additional fish tissues (more than the other three programs), and it is aimed at monitoring ecosystem health. Published reports of this program compare the fish tissue contaminant data with a wide range of effects thresholds including ones taken from the scientific literature.

2.2.2 State Programs

Fish tissue monitoring for contaminants occurs in all US states, whether as part of the federal, state or other programs. These are typically aimed at providing information for human fish consumption advisories.

Washington State

The Washington State Toxics Monitoring Program (WSTMP) was started in 2001. It is well designed, well reported on and is ongoing. The program is reviewed annually when the new data are evaluated and additional sites established accordingly. Permanent sites are sampled on a 5-year cycle. The types of contaminants analyzed are also reviewed annually. Washington's water quality standards criteria for toxic contaminants were issued to the state under the EPA's 1992 National Toxics Rule (NTR). Exceedance of the NTR criteria may lead to regulatory action.

Ohio

Ohio's Cooperative Fish Tissue Monitoring Program: Fish Tissue Environmental Assessment Program targets sites of concern. Specifically, the sites typically include the sampling of fish at an upstream reference site and three sequential downstream sites. Ohio EPA Fish Tissue Reporting Limits (FT RLs) are used to evaluate environmental and human health. The US FDA Action Levels are also used to develop sport-fish consumption advisories for humans.

Iowa

The Regional Ambient Fish Tissue Monitoring Program (RAFT) is used in Iowa and Missouri. This overview focuses on Iowa. Fish tissue contaminants are investigated in both rivers and lakes, including border sites on the Mississippi River.

The program involves the sampling of three types of sites:

1. *Trend sites* are considered as permanent from which, whole fish (specifically carp species), composite samples are collected to detect temporal trends in contaminant concentrations. These data are also used to identify new contaminants entering the food chain. Half of the *trend sites* are sampled in odd or even number years.

2. *Status sites* are used to screen for contamination issues related to human consumption of fish and measures of the environmental health of waterbodies. Composites of fillets from predatory fish and bottom-dwelling, omnivorous fish are analysed. *Status sites* are sampled approximately at a five year frequency for rivers or 10 years for lakes.

3. If the concentrations of contaminants in fish from the *status sites* exceed state advisory guidelines (i.e., IDNR levels of concern), the RAFT program conducts follow-up monitoring at these sites (thereafter referred to as *follow-*

up sites). Follow-up sampling is also conducted every other year at waterbodies with consumption advisories.

2.2.3 Program objectives

The specific objectives of the US programs monitor contaminants in fish tissues to determine the following:

- safety of the consumption of fish by humans,
- changes in fish contaminant levels over time, and
- potential effects on ecosystem health, specifically wildlife feeding on fish.

2.2.4 Selection of sites for monitoring

Selection of sampling sites in the US programs generally involves a combination of the following strategies:

- sampling at the sites immediately downstream or in the near vicinity of identified sources of pollution,
- random sampling design to provide overall perspective on the health of the watersheds, and
- sampling of sites away from likely sources of pollution in order to get a description of the general health of a water body or river

The four federal programs, especially NAQWA, are good examples of multi-faceted sampling strategies.

2.2.5 Fish collection for ecosystem health assessment

The following sections (2.2.5 to 2.2.9) deal with the collection of fish specifically for the purpose of monitoring ecosystem health. In most of the reviewed US studies at least two types of fish, from different trophic levels, are collected per site: predator species/sport fish and bottom-dwelling omnivorous fish. Each program has a list of target species listed in order of preference. Bottom-dwelling omnivorous fish are often targeted for ecosystem health.

Typically whole fish composite samples are collected. In order to reduce statistical variance, 5-10 adult fish of similar size, same species and sex (eg, for vitellogen analysis in some studies only) are collected, killed and the whole bodies homogenized (and see Appendix 2 for details of the methods in the seven US programs). Since gut contents contribute to whole fish homogenates (potentially increasing the variability of contaminant concentrations among the sampled fish), it is important to use at least five fish per composite sample to reduce statistical variance.

2.2.6 Handling methods

The US fish tissue contaminant monitoring programs follow stringent field and laboratory sampling procedures which are described in detail and are readily available (e.g., see details in Appendix 2). A range of techniques can be used to collect the fish - electrofishing being the favoured method. If seining is used to capture the fish, the nets have to be completely free of potential contaminants. Depending on the duration of sampling and transportation, the fish need to be stored either on ice, or dry ice, until they're processed for analyses. Fish can be processed in the field or in the laboratory for non-biomarker sampling. In studies involving biomarkers, live, subdued fish are processed in the field. Liquid nitrogen is required to preserve samples for EROD activity (see BEST program methods reference). Fish are handled with clean vinyl or nitrile gloves and allowed to come into contact only with pre-cleaned dissection tools and processing trays. Regardless of type of processing the fish/fish fillets are double or triple wrapped in pre-cleaned, heavy duty aluminum foil and then placed in zip-lock plastic bags and placed on ice. Aluminum foil has been used to wrap fillets in contaminant studies for a long time. There appears to be no evidence of metal contamination of fish tissues from the foil.

2.2.7 Laboratory analyses

At the laboratory the whole fish or fillet composites are homogenized. Typically around 150 g of tissue homogenate is needed for comprehensive analyses of organic contaminants and trace elements, though some studies (NLFTS) required up to 550 g.

The laboratory methods used are also described in detail in documents for each US program (see Appendix 2). The principal concerns with the analytical laboratories are that they are properly accredited (i.e., follow appropriate quality assurance or quality control procedures) and that the method detection limits (MDLs) are below the environmental guidelines or effects thresholds.

2.2.8 Effects thresholds

There is a wide variety of contaminants in aquatic ecosystems which can bioaccumulate in fish tissues. Interpretation of the concentrations of fish tissue contaminants in terms of environmental effects thresholds is dependant on the availability of relevant toxicological studies. In some cases these studies may not meet specific or minimal requirements, and thus, this can impair the development of formal guidelines. However, a variety of less stringent effects thresholds or other measures may also be developed to determine ecological effects. For example, some of the US programs include a variety of environmental health measures such as "benchmarks", "screening values", "criteria for the protection of wildlife" and "reporting limits." Examples of various effects thresholds for eacf of the US programs are in Appendix 2. Ecotoxicological research also needs to keep up with new and emerging contaminants in aquatic food webs.

2.2.9 Databases

The three ongoing federal monitoring programs in the US and the Washington State Toxics Monitoring Program all have searchable databases of results accessible via the internet. For more information see Appendix 2. The NLFTS data will eventually be uploaded to the US EPA's national STORET database system. This database also includes other related information such as water quality and sediment data.

2.3 COMPARISON OF CANADIAN AND US PROGRAMS

2.3.1 Scope of monitoring programs

The following summaries in this section illustrate some of the differences between the fish contaminant monitoring programs in Canada and the US.

On a national scale, Canada has the *Environmental Effects Monitoring (EEM) Program* that includes sampling of contaminants in fish tissues (e.g., dioxins, furans and metals). The monitoring programs are required under the Fisheries Act and are funded by the pulp and paper and metal mining industries. In addition, the Canadian federal government funds the Northern Canadian fish tissue monitoring programs in the Yukon, Nunavut and Northwest Territories. The main objective of these programs is to monitor fish contaminants primarily for human effects (protection of traditional foods). The Eastern Provinces fish contaminant monitoring program is focused on mercury and human health.

In Canada, only Quebec and Ontario have province-wide fish contaminant monitoring programs. The Ontario program tests for a wider range of contaminants than the Quebec program, and both monitor only sport fish for fish consumption advisories for humans. Smaller studies or programs are found in the rest of Canada, none of those comprising a province-wide or a territory-wide monitoring program.

The US has three nation-wide, federally-funded monitoring programs:

1. National Water Quality Assessment Program (NAQWA)
2. Biomonitoring of Environmental Status and Trends: Large River Monitoring Network (BEST:LRMN)
3. National Lake Fish Tissue Study (NLFTS)

Of these, the BEST:LRMN is the only long-term monitoring program. The program objectives are to determine nation-wide trends and patterns of fish contaminants in large rivers and tributaries, and it links the contaminants to fish or ecosystem health. The other two US nation-wide programs, NAQWA and NLFTS, collect both sport fish for human effects and bottom-dwelling fish for ecosystem effects. These programs tend to comprise discrete surveys rather than continuous long-term monitoring. The NLFTS was originally planned as a four-year study of US lakes, however, it may be extended depending on funding. The NAQWA program is composed of many Study Units each representing a major watershed. Depending on the contaminant results, the monitoring may be one time event or ongoing in individual watersheds.

The governments of Canada and the US are involved in the Great Lakes Fish Monitoring Program (GLFMP) since the 1970s. In this program, fish data from the Great Lakes are used in both fish consumption advisories (humans) and for monitoring and protection of the aquatic ecosystems and piscivorous birds. Both US EPA and CCME guidelines, including fish contaminant thresholds (see Appendix 2) are used in the final Great Lakes Water Quality Agreement (GLWQA) Criteria which are part of the GLFMP monitoring program.

All of the US states have state-wide fish tissue contaminant monitoring programs, at least for fish consumption advisories for humans. The three state-wide programs reviewed here monitor a wide range of contaminants and compare their concentrations against guidelines for human consumption and protection of fish-eating wildlife.

2.3.2 Fish tissue types

In the seven US programs reviewed, bottom-dwelling fish (such as catfish and suckers) were consistently used for monitoring of ecosystem health effects. Six of the programs used whole fish homogenates and one used muscle for contaminant analyses. The BEST program, in addition, collected other tissue samples such as liver and spleen. In Canada, only eight of the 32 monitoring studies summarized (details of tissues sampled in are Appendix 1) used whole fish homogenates. These eight studies mostly concerned aquatic ecosystem health rather than consumption advisories for humans. The other 24 Canadian studies, used either muscle fillets or samples from muscle and liver tissues. In general, muscle fillets of sport fish are used for fish contaminant monitoring focused on fish consumption advisories for humans.

2.3.3 Contaminants

The contaminants monitored in fish are similar in the US and Canada. Several programs in both countries only monitor for mercury in fish. While other programs focus on particular contaminant types typical of specific activities. For example, metals and trace elements, such as selenium, associated with mountain coal mines and uranium mines in western Canada, and dioxins, furans or other contaminants found in pulp and paper mill effluents. The most comprehensive Canadian and US programs, analyze the fish tissues for the following types of contaminants: PCBs, trace elements and metals, dioxins and furans, organochlorine pesticides, organophosphate pesticides, semivolatile organic compounds (include phenols and PAHs) and brominated flame retardants (e.g., PBDEs). In recent years, some programs (e.g. GLFMP) have also scanned the fish tissues for new or emerging contaminants of concern with respect to environmental effects. These include perfluorinated compounds, musk fragrances, alkylphenol ethoxylates (APEs), pharmaceuticals (human and veterinary), personal care products and flame retardants (in addition to PBDEs).

2.3.4 Availability of program results

Published reports are available online for a few of the Canadian programs. Full comprehensive reporting of the programs, (stating objectives, methods, results and trend analysis) is rare for the Canadian programs. In comparison, the seven US programs reviewed here are well reported on. However, that was one of the criteria used to select the programs for this review. Most of the other States do not produce interpretative reports for their monitoring programs with some exceptions, such as California, New Jersey and Virginia.

In contrast to the US programs reviewed, the Canadian programs (with the exception of the EEM program) do not provide online accessibility to the data. The US databases are of great value, especially when comparing geographic areas, trends in time or comparing fish tissue concentrations with other environmental parameters such as water quality, invertebrates and sediment contaminants.

3 PART II: SUMMARY OF FISH CONTAMINANT STUDIES IN ALBERTA

The objective of Part II was to prepare a detailed inventory of the available fish tissue contaminant studies for Alberta and to summarize the scope of the studies (i.e., from 1970 to 2005). Information on the Alberta inventory were obtained as detailed here:

- From technical experts in Alberta Environment (AENV) and Alberta Sustainable Resource Development (ASRD).
- Following up on potentially relevant studies from the list produced by searching the Fisheries Management Information System (FMIS) database of Alberta Sustainable Resource Development (ASRD), using the search terms metal, PCB, DDT, tissue, contaminant, toxic, mercury and pesticide.
- Following up on the suggested contacts and sources of information provided by AENV and ASRD.
- Contacts with researchers in this field, and searches for published reports and papers in the scientific literature using the University of Alberta library, Golder library and internet search engines.

Not all the study reports (or data) identified on the FMIS list were available for this review. Thus, effort was focused on materials which were readily available. Some reports were not included because they were obtained too late. These included baseline and operational environmental monitoring for the Slave Lake Pulp Mill (E.V.S. Consultants 1990, 1991, 1992) and other research or issue-related sampling (e.g., Holm *et al.* 2005; Palace 2004).

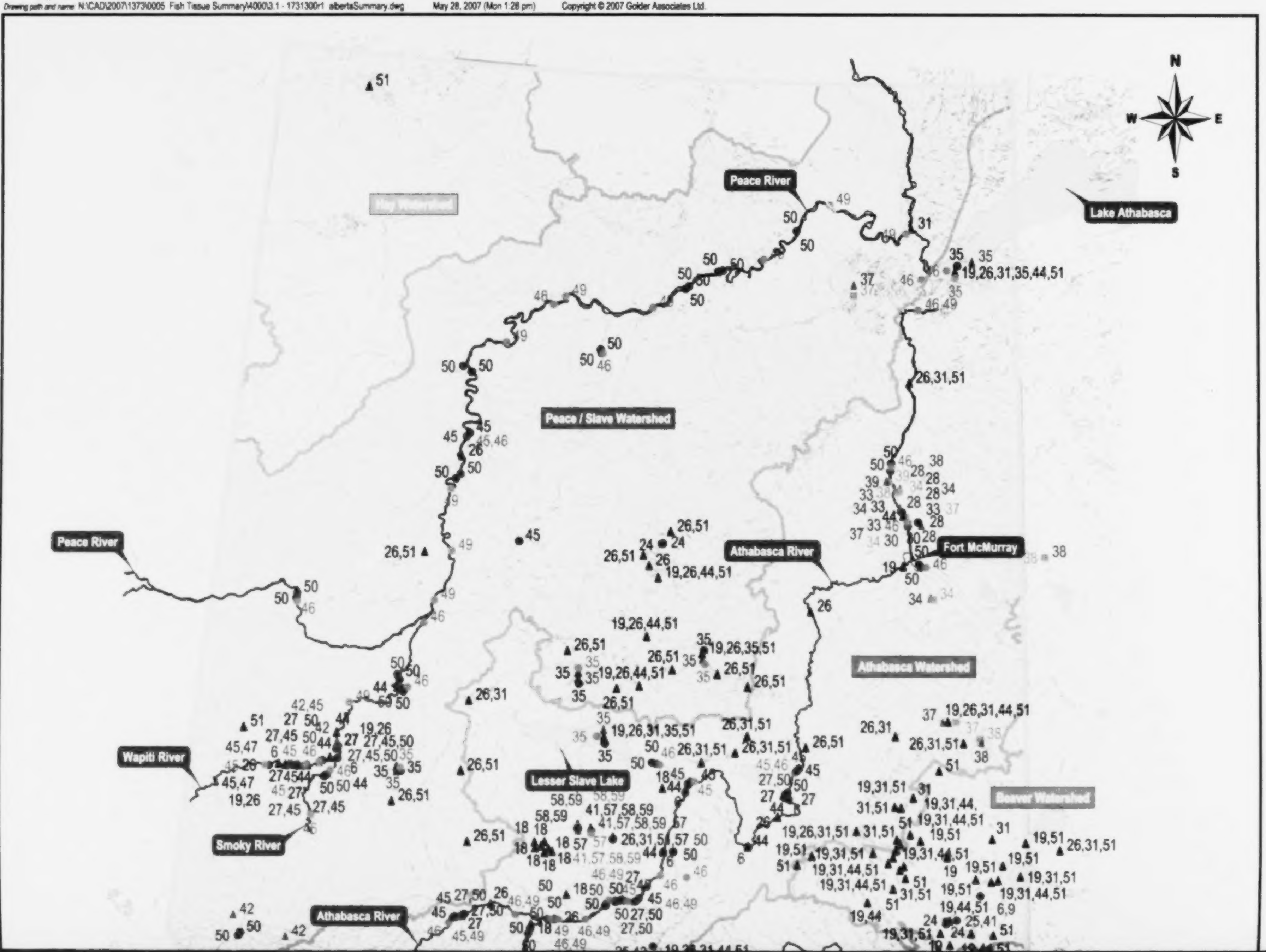
In total, fifty-nine reports or compilations of fish tissue data for Alberta were reviewed. The contaminants examined included organochlorines and organophosphate pesticides, dioxins and furans, metals, trace elements, PCBs, PAHs and related chemicals, and organic tainting compounds (see detailed list in Appendix 3).

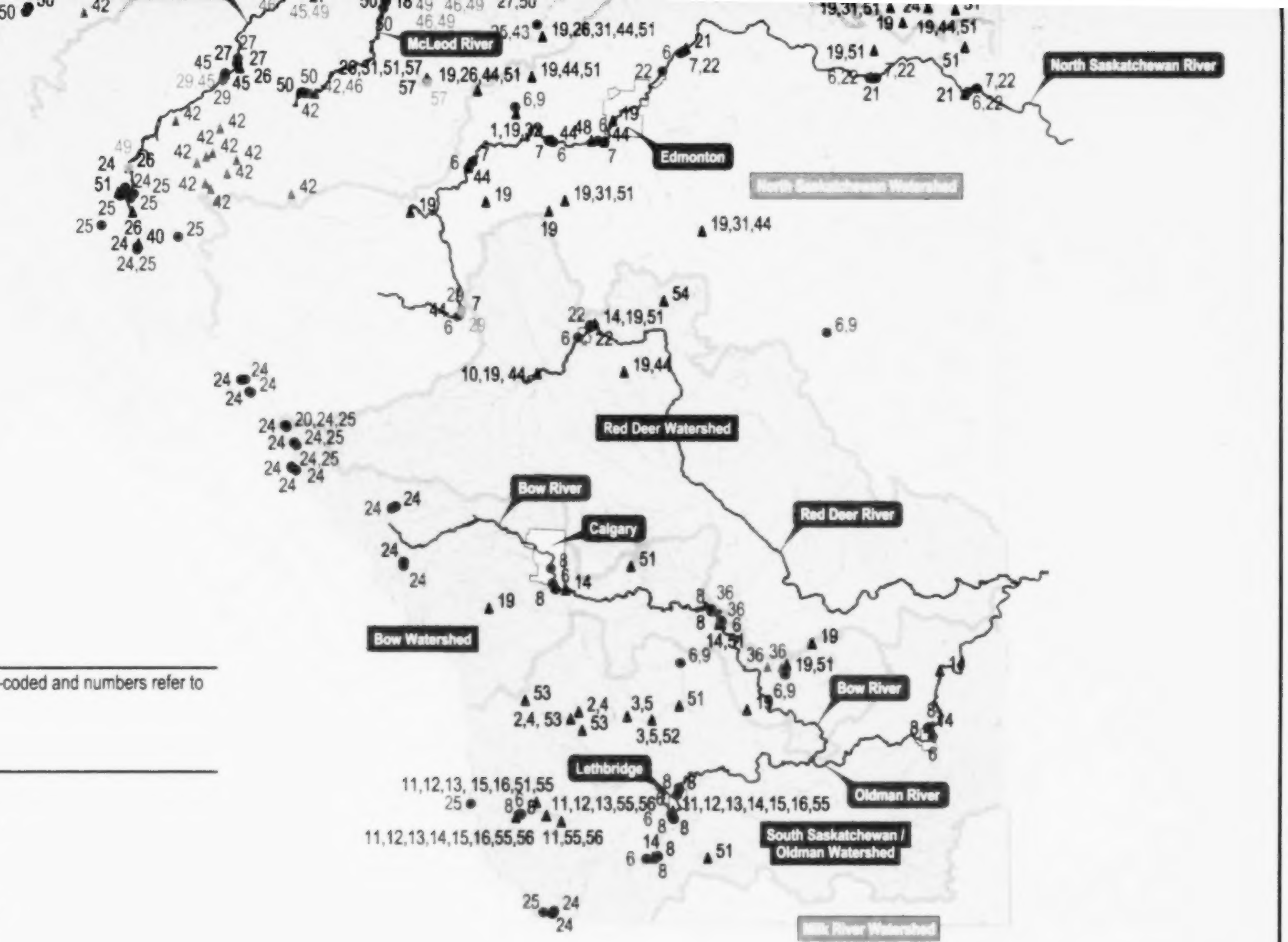
Part II includes:

- a map of Alberta summarizing the inventory including the spatial distribution of the contaminant studies within major river basins, specific sampling locations, and contaminant types analysed (Figure 3.1). Table 3.1 is a more detailed list of the studies.
- general summaries of main trends in effort over time (decades) and by major watershed, fish species or contaminant type (based on the information from report summaries and Figure 3.1).

Images used:

Drawing path and name: N:\CAD\2007\1373\0005 Fish Tissue Summary\4000\3.1 - 1731300r1 albertaSummary.dwg May 28, 2007 (Mon 1:28 pm) Copyright © 2007 Golder Associates Ltd.





NOTE

Contaminant analyses are colour-coded and numbers refer to studies listed in Table 2.1.

LEGEND

- River or stream
- Watershed boundary
- Open water
- ☐ Large settlement
- ● Chlorinated phenolics
- ● Dioxins
- ▲ Mercury
- ● PAH
- ● PCB
- ● Pesticides
- ▲ Selenium
- ● Tainting
- ▲ Total metals

Reference: Digital data obtained from DMTI, used under license.
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: UTM Zone 12

50 0 100
Scale Km

Project
Alberta Environment
Element II of the Development of a Monitoring and Reporting Program for Fish Contaminants in Alberta

Title
Fish Tissue Contaminant Sampling in Alberta, 1978-2006

Golder Associates
Edmonton, Alberta

Project No.		07-1373-0005	File No	1731300r1
Design	EJ	19/03/07	Scale As shown	Rev 0
Cadd	RW	19/03/07	**Figure: 3.1**	
Check				
Review				

Table 3.1 List of Alberta Fish Contaminant Studies Shown in Figure 3.1.

#	Report	Years of Data	Total # of Fish	Fish Species
1	ASRD. 1995. Enviro-Test chemical analysis report for mercury concentrations in fish captured within the Keephill and Genesee cooling ponds.	1995	24	WALL, NRPK, SHRD, LNSC, WHSC
2	ASRD. 2003. Unpublished data for Willow Creek and the Pine Coulee Reservoir.	2003	142	BKTR, BNTR, BURB, LNSC, MNSC, MNWH, NRPK, WALL, WHSC, LKCH, LNDC, TRPR
3	ARC. 2004a. Unpublished data for the Little Bow River.	2004	195	NRPK, WHSC, BURB, YLPR
4	ARC. 2004b. Unpublished data for Willow Creek and the Pine Coulee Reservoir.	2004	112	BURB, LNSC , NRPK, WALL, WHSC
5	ARC. 2005. Unpublished data for the Little Bow River.	2005	218	NRPK, WHSC, BURB, LNSC
6	AEC. 1984a. Methoxychlor and 2,2-bis (p-methoxyphenyl)-1, 1-dichloroethylene residues in fish in Alberta.	1980-1983	1284	LKWH, MNWH, BNTR, RNTR, LNSC, SHRD, WHSC, FLCH, BURB, LKST, ARGR, SAUG, WALL, GOLD, NRPK
7	ARC. 1984b. Partitioning of polychlorinated biphenyls in the North Saskatchewan.	1980-1983	492	BRTR, MNWH, SAUG, WALL, NRPK, GOLD, LNSC, WHSC, SHRD
8	AEC. 1983d. Chemical residues in fish from five rivers in southern AB.	1980 & 1982	414	RNTR, BRTR, MNWH, WALL, SAUG, NRPK, WHSC, LNSC, LKWH, BURB, LKST, SHRD, DLVR, NRDC
9	AEC. 1983a. Chemical residues in fish tissues in Alberta. I.	1981	187	WHSC, LKWH, NRPK, WALL, LNSC
10	AEC. 1989. A five-year study of mercury in fish from a newly formed reservoir.	1983-1987	~291	NRPK, WHSC, LNSC, MNWH, BURB, RNTR
11	AEC. 1993. Oldman River Dam: mercury in fish-interim report 1991.	1991	409	RNTR, MNWH, BLTR, WHSC, LNSC, NRPK, BURB
12	AEC. 1994a. Oldman River Dam: Mercury in Fish - Interim Report 1992.	1992	203	MNWH, RNTR, BLTR, WHSC, LNSC, NRPK, BURB
13	AEC. 1994b. Oldman River Dam: mercury in fish - interim report 1993.	1993	135	RNTR, MNWH, BLTR, WHSC, LNSC
14	AEC. 1984c. Mercury in fish from six rivers in Southern Alberta.	1982-1983	~350	LNSC, WHSC, SHRD, MNWH, LKWH, RNTR, BNTR, DLVR, WALL, SAUG, GOLD, NRPK, BURB, LKST
15	AEC. 1997. Oldman River Dam: Mercury In Fish (1991-1995)	1995	260	BLTR, BNTR, BURB, CTTR, LKTR, LNSC, MNWH, NRPK, RNTR, WHSC
16	AEC. 2002. Oldman River Dam: mercury in fish, 2000.	2000	252	BLTR, LNSC, MNWH, RNTR, WHSC, CTTR, BURB
17	Alberta Sessional paper 504/90. 1988. Preliminary Results of Fish and Sediment Sampling Program for Dioxins and Furans.	N/A	11	LNSC, WHSC
18	Allen et al. 2005. Methyl mercury concentrations in macroinvertebrates and fish from burned and undisturbed lakes on the Boreal Plain.	2000-2001	6	BRST, PRDC
19*	AE. 1987. Analytical Results from fish Submitted for Mercury Analysis up to May 21, 1987.	1970-1987	1915	NRPK, GOLD, WHSC, FLCH, LNSC, WALL, LKWH, ARGR, MNWH, CISC, BURB, RNTR, BNTR, SAUG, SHRD, YLPR
20	Campbell et al. 2000. Organochlorine transfer in the food web of subalpine Bow Lake, Banff National Park.	1994	28	LKTR, MNWH
21	AEC. 1983b. Chemical residues in fish tissues in Alberta. II.	1982	159	WALL, SAUG, GOLD, NRPK, LNSC, SHRD, QUIL, WHSC
22	AEC. 1983c. Chemical residues in fish tissues in Alberta. III.	1980-1982	~ 500	GOLD, WALL, NRPK, SAUG, LNSC, WHSC, SHRD, LKWH, BURB, QUIL
23*	Westworth. 1997. Northern River Basin Study Project Report No. 145, Historical Compilation of Fish Tissue Contaminant Data.	N/S	N/S	N/S
24*	Donald et al 1993. Polychlorinated biphenyls and organochlorine pesticides in the aquatic environment along the continental divide region of AB and BC.	1991-1992	144	LKTR, CTTR
25	Donald et al. 1998. Chlorobornanes in water, sediment and fish from toxaphene treated and untreated lakes in western Canada.	1994	91	LNSC , BKTR, RNTR, MTWH, LKTR

#	Report	Years of Data	Total # of Fish	Fish Species
26	Donald et al 1996. Northern river basin study project report No. 105: Contaminants in Environmental Samples- Mercury in the Peace, Athabasca and Slave River basins.	1973-1994	1631	NRPK, LKWH, MNWH, WHSC, LNSC, WALL, GOLD, BURB, BLTR
27	Evans and Muir. 2004. Contaminant biomagnification in specific reaches of the Peace-Athabasca river ecosystem – study highlights.	2002	N/A	LKCH, BURB, LNDC, LNSC
28	Golder. 1996a. Aquatic baseline report for the Athabasca River, Steepbank and Muskeg Rivers in the vicinity of the Steepbank and Aurora Mines.	1995	118	GOLD, WALL, LNSC
29	Golder. 1996b. Environmental Effects Monitoring: Cycle I Final Report.	1995	182	LNSC, MNWH
30	Golder. 1999. Oil Sands Regional Aquatics Monitoring Program.	1998	64	LNSC, GOLD, WALL, LKWH
31	Golder. 2000. Assessment Of Mercury levels in Wabamun Lake.	1973-1996	1400	NRPK
32	Golder. 2001. 2001 Wabamun Lake Fish Monitoring.	1996 & 2001	85	NRPK, LKWH
33	Golder. 2002. Oil Sands Regional Aquatics Monitoring Program.	2001	30	WALL, LKWH, NRPK
34	Golder. 2003. Oil Sands Regional Aquatics Monitoring Program	2002	176	LKWH, WALL, NRPK
35	Golder. 2004. Fish contaminant study for Treaty 8 First Nation communities in northern AB.	2003	601	LKWH, NRPK, WALL, GOLD
36	Golder. 2006. Bow City Power Project: aquatic resources baseline.	2001-2005		LKWH, NRPK
37	Hatfield. 2004. Regional Aquatics Monitoring Program.	2003	91	WALL, LKWH, NRPK
38	Hatfield. 2005a. Regional Aquatics Monitoring Program.	2004	72	WALL, LKWH, NRPK
39	Hatfield 2005b. Regional Aquatics Monitoring Program	2005	55	LKWH, WALL
40	Kelly et al 2006. Forest fire increases mercury accumulation by fishes via food web restructuring and increased mercury inputs.	1994, 2001, 2003	N/S	RNTR, LKTR, BLTR, CISC
41	Komex. 1995. Summary report of the fish tissue monitoring program at the Alberta Special Waste Treatment Center.	1985-1994	N/S	BRTR, WHSC
42	Mackay. 2006. Selenium concentrations in the tissues of fish from the Upper McLeod and Upper Smoky River systems.	1999 - 2001	476	RNTR, BLTR, BKTR, ARGR, LNSC, MNWH
43*	Miskimmin et al 1995. Chlorobornanes in sediments and fish 30 years after toxaphene treatments of lakes.	1993	9	RNTR
44	Moore et al. 1986. Mercury residues in fish from twenty-four lakes and rivers in Alberta.	1984	603	NRPK, GOLD, WHSC, FLCH, LNSC, WALL, ARGR, MNWH, LKWH, BURB, RNTR, BNTR, SAUG
45	Muir and Fraikin. 2004. Spatial and temporal trends of organochlorine contaminants in fish from Alberta's northern rivers.	1998-2000	133	BURB, BLTR, MNWH, LNSC
46*	Muir and Pastershank. 1997. Environmental contaminants in fish: spatial and temporal trends of polychlorinated dibenzo-p-dioxins and dibenzofurans, Peace, Athabasca and Slave River Basins, 1992-1994.	1992-1994	~465	NRPK, MNWH, WALL, GOLD, LNSC, BURB, LKWH
47	AEC. 1987. Toxicity and environmental chemistry of wastewater from kraft pulp and paper mill: fish toxicity studies.	1981-1982	N/S	FLCH, LNSC, NRPK
48	Munson 1978. The biology of goldeye, *Hiodon alosiodes*, in the North Saskatchewan River with special reference to mercury contamination in this species of fish.	1973-1976	581	GOLD, WALL, SAUG, NRPK, LNSC, WHSC, SLRD, SHRD
49	Pastershank and Muir. 1995. Contaminants in environmental samples: PCDDs and PCDFs downstream of bleached kraft mills, Peace and Athabasca Rivers, 1992.	1992	276	NRPK, LNSC, WALL, BURB, GOLD, MNWH
50*	Pastershank and Muir. 1996. Environmental contaminants in fish: Polychlorinated Biphenyls, Organochlorine Pesticides and Chlorinated Phenols, Peace Athabasca Slave Rivers Basins, 1992 to 1994.	1992-1994	~417	NRPK, MNWH, WALL, GOLD, LNSC, BURB
51*	AFW. 1992. Summary of analytical data provided by Ken Bodden - Provincial Commercial and Domestic Fisheries Specialist (AFW)	1972-1992	2169	GOLD, ARGR, BURB, YLPR, WALL, NRPK, SAUG, LKST, SC, LNSC, WHSC, BRTR, BKTR, LKTR, RBTR, CISC, WH

#	Report	Years of Data	Total # of Fish	Fish Species
52	Wharmby and Feng. 2003. Baseline Fish Mercury Levels in the Little Bow River.	2002	80	NRPK, WHSC
53	Wu. 1998. Baseline Fish Mercury Levels in Willow Creek Upstream and Downstream of Pine Coulee, 1997.	1997	131	BURB, CTTR, MNWH, NRPK, RNTR, LKCH, LNDC, TRPR
54	Wu et al. 1995. Mercury in fish from the narrows in Parlby Creek - Buffalo Lake.	1993	19	NRPK, LNSC, WHSC
55	Wu et al. 1996. Oldman River Dam: mercury in fish.	1994	250	RNTR, MNWH, BLTR, WHSC, LNSC, NRPK, BURB
56	Wu, 1998. Oldman River Dam: mercury in fish.	1997	213	BLTR, LNSC, MNWH, RNTR, WHSC, BURB
57	AHW. 2004. Swan Hills Waste Treatment Centre Long-Term Follow-Up Health Assessment Program 1997-2002.	1997-2001	77	BRTR, NRPK
58	Komex. 2003. 2002 Fish Tissue Monitoring Swan Hills Treatment Centre.	2002	51	BRTR
59	Komex. 2004. 2003 Fish Tissue Monitoring Swan Hills Treatment Centre.	2003	26	BRTR

* Some Lakes could not be found - see specific sites.

N/S – not specified.

3.1 MONITORING EFFORT FROM 1970-2005

The studies summarized herein cover fish tissue data collected over four decades beginning in 1970. Overall there was an increase in the total number of studies from the 1970s to 1990s, and up to 2005 (Table 3.2). Data from the 1970s is presented in five reports. Fifteen reports contain fish contaminant data from the 1980s. Data for the 1990s is presented in 28 reports and a similar monitoring effort occurred in the 2000s, with 22 reports (Table 3.2). Although the majority of reports (34) represented one-year studies, 24 were multi-year programs with three continuing for 20 or more years. The longer-term studies were summary reports of historic mercury levels for Wabamun Lake (Golder 2000) and the Northern River Basin Study (Donald et al. 1996), and a mercury dataset (1972-1989) [2] provided by ASRD. Two reports were not included in this analysis because the study duration was not reported in one source (i.e., Alberta Sessional paper 504/90, 1988). While the other was a compilation of historical data as part of the Northern River Basins Study (Westworth 1997), and it was excluded to avoid duplication.

Table 3.2 Number of Alberta Studies per Decade and Major Watershed from 1970-2005.

Decade	Hay	Peace	Athabasca	Beaver	North Saskatchewan	Red Deer	South Saskatchewan	Total Reports[(a), (b)]
1970s	3	4	4	3	4	3	3	**5**
1980s	3	7	7	3	9	8	7	**16**
1990s	2	8	17	2	6	3	12	**28**
2000s	0	4	14	0	1	0	7	**22**
Total Reports[(a), (b)]	**3**	**13**	**30**	**3**	**14**	**9**	**24**	

[(a)] Includes reports on all contaminants, including dioxins, furans, and pesticides, excludes the review report by Westworth (1997), "Historical Compilation of Fish Tissue Contaminant Data", to avoid repetition.

[(b)] Note that some reports contained data for more than one decade or watershed.

3.2 MONITORING EFFORT ACROSS WATERSHEDS

Overall, fish tissue contaminant data are available from most watersheds (Figure 3.1, Table 3.2). Among the major river basins, most studies were for the Athabasca and South Saskatchewan river systems (total number of reports = 30 and 24, respectively) (Table 3.2). Lower number of studies were found for the North Saskatchewan and Peace river systems (total number of reports = 14 and 13, respectively) (Table 3.2). The high number of studies for the Athabasca River after the 1980s in particular, was related to increased efforts associated with several new or expanded pulp and paper mills, the Northern River Basins Study, and the follow-up Northern Rivers Ecosystem Initiative. Smaller numbers of studies were found for the Red Deer, Hay and Beaver river systems. No data were found for the Milk River, part of the Missouri/Mississippi river system.

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[2] Data were from three sources: Alberta Environmental Centre (now ARC), Vegreville (data from 1985-1989); Fisheries Management, Alberta Sustainable Resource Development (provincial samples from 1982-1989); and Department of Fisheries and Oceans (commercial fisheries data from 1970 to 1985)

3.3 EFFORT PER SPECIES IN LOTIC AND LENTIC WATERS

The most commonly studied species were northern pike and longnose sucker (38 and 37 reports, respectively) (Table 3.3). Sixteen reports were on sport fish, one report focused entirely on sucker species, and only one report concerned other forage fish. Six reports focused on a range of forage fish, sucker, and sport fish species. Overall, the available fish contaminant data for Alberta contained results for 28 species of fish collected since 1970 (Table 3.3). Most of the species collected were sport fish (18 species), comprising 11 coldwater species and 7 warm-water species. Of the forage fish sampled, the species that were most frequently sampled included flathead chub (four reports), lake chub (three reports) and longnose dace (three reports).

Fish contaminant research and monitoring in Alberta has been conducted in both lotic and lentic waters. Monitoring effort has been comparable between these systems in that there are 14 reports on fish contaminants from lentic waters *versus* 19 reports from lotic waters. A total of 25 reports assessed fish contaminants in both lentic and lotic waters.

3.4 MONITORING EFFORT PER CONTAMINANT

In addition to the general monitoring effort per study basin, we included a summary of monitoring effort for the most common contaminant types sampled (Tables 3.4 and 3.5). The most common contaminants in decreasing order were mercury, PCBs, metals (selenium, arsenic, lead, and total metals), DDT, toxaphenes and PAHs. Mercury was clearly the most investigated element, having been evaluated in fish tissue in 35 reports (Tables 3.4 and 3.5). Using "report years" as a proxy of effort (i.e., the sum of the study durations for the relevant reports), there has been approximately four-fold more sampling for mercury than any other contaminant examined in Alberta (Table 3.5).

Table 3.3 Number of Alberta reports per fish species, and the minimum and maximum lengths of the fish analysed for contaminants

		Common name	Species abbreviations	# Reports	Minimum length (mm)	Maximum length (mm)
Forage fish		Brook stickleback	BRST	1	48	62
		Flathead chub	FLCH	4	214	254
		Lake chub	LKCH	3	60	118
		Longnose dace	LNDC	3	52	80
		Pearl dace	PRDC	1	56	72
		Trout perch	TRPR	2	40	84
Sucker		Longnose sucker	LNSC	37	55	550
		Mountain sucker	MNSC	1	60	65
		Quillback	QUIL	2	352	602
		Shorthead redhorse	SHRD	9	326	514
		Silver redhorse	SLRD	1	N/A	N/A
		Sucker spp.	Sucker	1	438	507
		White sucker	WHSC	28	67	830
Sport	Coldwater	Arctic grayling	ARGR	5	223	390
		Bull trout	BLTR	11	85	590
		Brown trout	BNTR	6	130	507
		Brook trout	BRTR	7	100	504
		Cisco	CISC	3	335	425
		Cutthroat trout	CTTR	4	186	354
		Dolly Varden	DLVR	2	248	255
		Lake trout	LKTR	6	244	665
		Lake whitefish	LKWH	18	171	603
		Mountain whitefish	MNWH	24	50	485
		Rainbow trout	RNTR	18	86	564
		Whitefish spp.	Whitefish	1	212	614
	Warm Water	Burbot	BURB	25	120	862
		Goldeye	GOLD	16	170	422
		Lake sturgeon	LKST	4	695	941
		Northern pike	NRPK	38	106	1147
		Sauger	SAUG	10	251	564
		Walleye	WALL	26	102	867
		Yellow perch	YLPR	3	84	325

Table 3.4 Number of Alberta Reports for Common Fish Tissue Contaminants in Major Watersheds from 1970-2005

Contaminant	Total Reports / Watershed						
	Hay	Peace	Athabasca	Beaver	North Saskatchewan	Red Deer	South Saskatchewan
Arsenic	0	1	11	0	1	0	1
DDTs	0	2	3	0	4	2	5
Lead	0	1	11	0	1	0	1
Mercury	3	8	21	3	7	8	18
PAHs	0	0	3	0	0	0	0
PCBs	0	6	9	0	4	1	4
Selenium	0	2	11	0	1	0	1
Dioxins and Furans	0	4	5	0	1	0	0
Tainting Compounds	0	0	4	0	0	0	0
Total Metals	0	0	10	0	1	0	0
Toxaphenes	0	1	3	0	1	0	3

Table 3.5 Number of Alberta Reports per Common Contaminant in the 1970s, 1980s, 1990s and 2000s

Contaminant	Report Years[a]	Total Reports / Decade				Total Reports
		1970	1980	1990	2000	
Arsenic	28	0	1	4	10	**12**
DDTs	17	0	4	3	2	**8**
Lead	28	0	1	4	10	**12**
Mercury	160	5	9	18	21	**41**
PAHs	3	0	0	2	1	**3**
PCBs	38	0	6	6	6	**15**
Selenium	28	0	1	4	11	**12**
Dioxins and Furans	6	0	1	2	2	**4**
Tainting Compounds	4	0	0	0	4	**4**
Total Metals	20	0	1	3	8	**10**
Toxaphenes	14	0	3	4	1	**7**

[a] Calculated as the sum of the duration of reports (ie, years) per contaminant.

PCBs were the second most studied fish tissue contaminants in Alberta, reported in 16 studies. Since 1970, there has been a general increase in the range of contaminants being studied (Table 3.5). In the 1970's, mercury was the only contaminant studied in fish tissues. Then, monitoring of PCBs, selected metals (e.g., selenium, arsenic, lead and mercury), DDT, toxaphenes, and dioxins and furans began in the 1980s. Overall the monitoring of trace organic contaminants has remained at low number of studies and the sampling of metals has increased, especially in more recent years (Table 3.5).

3.5 USE OF EFFECTS GUIDELINES OR THRESHOLDS

Overall, the guidelines used in the Alberta studies were primarily those used to address the consumption of fish by humans. The Health Canada (or Health and Welfare Canada) human consumption guidelines were used in 27 studies and the Canadian Food Inspection Agency (CFIA) guidelines were used in eight studies. USEPA guidelines were only used in four studies. Environment Canada, Ontario Ministry for the Environment, and CCME guidelines to protect wildlife or bird consumers of fish, or a small number of other guideline sources, were used in just one or two studies each. Four of the studies did not cite the source of the guidelines used. A total of 16 studies did not compare fish tissue contaminant concentrations with any type of guideline. It is possible that the availability of guidelines may have been more limited for the older studies. Of the Alberta studies reviewed, 27 compared the contaminant concentrations to guidelines from a single source, such as Health and Welfare Canada or Environment Canada, and 11 studies used guidelines from multiple sources.

4 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

GOLDER ASSOCIATES LTD.

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APPENDIX 1

SUMMARY OF CANADIAN FISH CONTAMINANT MONITORING PROGRAMS

Program	**Spatial and long-term trends in organic contaminants and metals in fish species important to the commercial, sports, and domestic fisheries of Great Slave Lake and the Slave River ecosystem**
Region	NWT
Study Proponent	EC, AMAP
Program Status	Ongoing
Years of Data	1999 - ongoing
Sampling Frequency	annual
Overall Objectives	1. Develop a cost-effective, long-term monitoring strategy for assessing temporal trends in contaminant concentrations (and types) in key fish species inhabiting the Great Slave Lake ecosystem, including the Slave River. 2. Assess regional differences (and similarities) in contaminant trends, including investigations of the possible causal factors for these differences. 3. Integrate the Great Slave Lake and Slave River monitoring program with research and monitoring programs being conducted in the Peace and Athabasca River drainage systems (supported under the Northern River Ecosystem Initiative), the ongoing NCP-supported burbot monitoring program at Fort Good Hope on the Mackenzie River at Fort Good Hope (lead research scientist, Gary Stern), and the upcoming Slave River water and sediment monitoring program. This study builds on earlier research conducted during 1993-1996 on Great Slave Lake under NCP and the Slave River under the 1989-1994 Slave River Monitoring Study. It also complements ongoing studies in the Peace and Athabasca Rivers on contaminants in burbot, other fish, and other components of the river ecosystem.
Number of Sampling Locations	3 sites; lakes and river
Reasons for Choice of Sampling Locations	important fishing location
Study Design	long term monitoring of trends
Contaminants	metals, POPs
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	n/a
Total Sample Size	n/a
Tissue Sampled	n/a
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	Fish samples are sent to the National Hydrology Research Centre for initial examination, selection of fish to be analysed, and archiving. Fish are collected by northern community members. Selected fish are then sent to the National Water Research Institute for initial handling. Derek Muir is responsible for tissue preparation, extraction, and toxaphene analysis.
Analytical Methods	Gary Stern analyzes the sample extracts for POPs including PCBs, DDT, dieldrin, etc. Mike Whittle conducts the coplanar analyses and prepares the samples for possible future dioxin/furan analyses. Lyle Lockhart conducts the metal analyses (mercury, arsenic, and selenium). Carbon and nitrogen isotope analyses are conducted at NWRI-Saskatoon. contact researchers for further details.
Statistical Methods	n/a
Archived Samples	Yes - NWRI-Saskatoon, Burlington (Whittle, Muir) and Winnipeg (Stern)
Advantages	long-term monitoring to assess various contaminants of concern
Disadvantages	
Other Comments	
References	http://www.amap.no/ Evans, M.S. et al. 2000b.
Contacts	Marlene S. Evans National Research Centre, Environment Canada 11 Innovation Boulevard, Saskatoon, SK, S7N 3H5 (306) 975-5310; marlene.evans@ec.gc.ca

Program	**An investigation of factors affecting high mercury concentrations in predatory fish in the Mackenzie River Basin**
Region	NWT
Study Proponent	EC, AMAP
Program Status	Ongoing
Years of Data	1999 - ongoing
Sampling Frequency	annual
Overall Objectives	1. Conduct limnological studies to determine why predatory fish inhabiting some lakes in the Mackenzie River Basin have elevated mercury levels while fish in other, apparently similar lakes, have lower mercury levels. 2. Investigate the role of food web structure in the biomagnification of mercury by predatory fish. 3. Determine whether mercury flux rates to these high mercury lakes have increased in recent years and, if so, assess why this may have occurred. 4. Investigate whether it is possible to develop lake-specific remedial actions to reduce mercury concentrations in harvested fish from high-mercury lakes. 5. As part of the mercury studies, conduct limited determinations of persistent organochlorine pollutants (POPs) concentrations in predatory fish. This will allow us to compare mercury and organochlorine biomagnification rates in addition to assessing whether contaminant levels are below human health consumption guidelines.
Number of Sampling Locations	5 sites
Reasons for Choosing Sampling Locations	n/a
Study Design	long term monitoring of trends
Contaminants	metals and POPs
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	ARCH, BNTR, BURB, NRPK, LKWH, WALL, YLPR, CISC, LKTR, INCO, ARGR
Total Sample Size	n/a
Tissue Sampled	muscle and liver
Amount of Tissue	n/a
Additional Fish Health Variables	length, weight, age, growth rates, trophic position, diet
Environmental Health Variables	Freshwater benthos, freshwater sediments, higher plants, precipitation/snow, riverwater, lake water/suspended particulate matter
Sampling and Handling Methods	n/a
Analytical Methods	Total Hg and other metal analyses are conducted through the Freshwater Institute. Stable isotope analyses are conducted at NWRI-Saskatoon. Organochlorine analyses are conducted at the Freshwater Institute.
Statistical Methods	Where reporting formats for tissue concentrations differed, conversions between dry weight (dw) and wet weight (ww) were made and the assumptions used were specified. Because some heavy metals bioaccumulate, concentrations in animals are generally adjusted for size and/or age to allow meaningful comparison.
Archived Samples	Yes - Most archived samples reside at NWRI-Saskatoon
Advantages	long-term monitoring to assess various contaminants of concern
Disadvantages	Difficulties in interpretation typically arise owing to differences in the field and laboratory methods used as well as a lack of standardized reporting formats. These differences can obscure spatial patterns and hinder the integration and interpretation of data from different investigators. Standardized reporting procedures will increase the possibility of identifying spatial patterns.
Other Comments	
References	http://www.amap.no/ Evans, M.S. et al. 2000a.
Contacts	Marlene S. Evans National Research Centre, Environment Canada 11 Innovation Boulevard, Saskatoon, SK, S7N 3H5 (306) 975-5310; marlene.evans@ec.gc.ca

Program	**Athabasca Working Group environmental monitoring program**
Region	SK
Study Proponent	SERM, Industry, Community groups
Program Status	Ongoing
Years of Data	2000 - ongoing
Sampling Frequency	annual
Overall Objectives	The environmental monitoring program, subject to confirmation through detailed followup surveys, is the primary method to determine whether a loss has occurred as a result of mining emissions.
Number of Sampling Locations	15 sites; lakes
Reasons for Choosing Sampling Locations	reference waterbodies, which are known to be free of any potential mine-related contaminants. The effect stations are located in waterbodies that are considered important to each community.
Study Design	control/impact; survey
Contaminants	metals, inorganic ions, phophorus, radionuclides, trace elements
Effects Thesholds	**Human Consumption (SERM)** Hg 0.5 ug/g
Source of Guideline	SERM. 1999. (based on Health Canada)
Fish Species	NRPK, LKWH
Total Sample Size	n/a
Tissue Sampled	muscle
Amount of Tissue	800 g
Additional Fish Health Variables	length, weight, sex, maturity
Environmental Health Variables	air - radon gas, water quality; sediment chemistry; plants - chemical concentrations in the fruit of bog cranberry and blueberry, and from Labrador tea leaves; mammals - chemical concentrations in flesh from moose, barren-ground caribou, and lynx
Sampling and Handling Methods	Industry and local community members conduct the sampling. Gill nets and angling were used to collect fish. Ageing structures (cleithra/scales-northern pike and otoliths/scales-lake whitefish) have been collected and archived. All fish samples were frozen and shipped to SRC for analysis.
Analytical Methods	Analysis conducted at SRC. Where an individual fish did not provide sufficient material for sampling, two would be combined to meet the sampling requirement.
Statistical Methods	n/a
Archived Samples	n/a
Advantages	Monitoring changes near industrial regions
Disadvantages	Data is only collected for 2 fish species in lakes near First Nations communities that may be affected by mining activity in the area. Examines a limited suite of contaminants.
Other Comments	Program began in 2000. The data collected from each monitoring program year is kept within two Microsoft Access database formats. The program is conducted by local community members and industry staff.
References	Canada North Environmental Services. 2004. http://www.cameco.com/sustainable_development/clean_environment/awg.php
Contacts	Peter Vanriel (306) 652-4432

Program	**Selenium Monitoring in Sculpins**
Region	BC
Study Proponent	BC MOE, Coal Industry
Program Status	Ongoing
Years of Data	1998, 2002-ongoing
Sampling Frequency	annual
Overall Objectives	Determination of background Se concentrations in whole bodies of slimy sculpin (Cottus cognatus) collected from reference areas both inside and outside the coal zone.
Number of Sampling Locations	43 sites; streams/rivers
Reasons for Choosing Sampling Locations	reference sites from inside and outside BC's coal zone
Study Design	survey with comparisons between sites inside and outside the coal zone; long-term monitoring
Contaminants	selenium
Effects Thesholds	**BC Interim draft whole body guideline** 4ug/g dw (75% moisture) **USEPA Draft fish whole body criteria** 5.85 ug/g dw (summer sample), 7.9 ug/g dw (winter sample)
Source of Guideline	BCMELP (now BC MOE). 2001. USEPA. 2004.
Fish Species	SLSC, MNWH, BLTR, RNTR
Total Sample Size	178 samples
Tissue Sampled	whole body
Amount of Tissue	8 g
Additional Fish Health Variables	length, weight, age, total metals were analyzed but not reported
Environmental Health Variables	n/a
Sampling and Handling Methods	Slimy sculpin were collected opportunistically by MOE and coal mine personnel. At each site, replicate samples were collected. Samples comprised 1-15 sculpins per sample (to weigh ≥ 8 g) and were placed in individual bags as single tissue samples. MOE collected a total of 92 samples at 24 sites. Mine proponents collected a total of 86 samples at 21 sites. An average of 4 samples was collected per site. Limited sampling and analysis was also conducted for other species (mountain whitefish, bull trout, rainbow trout).
Analytical Methods	Otoliths were removed for age determinations. After processing, the sculpin samples were stored frozen, in their respective sample bags, prior to whole body total Se and percent moisture analyses. Note that whole body samples were also analyzed for total metals; however, those results are not reported here. ALS (conducting analyses for proponents) acid digested their samples, and analyzed the extracts with HVAAS. Maxxam (conducting analyses for MOE) acid digested their samples and analyzed the extracts with ICP-MS.
Statistical Methods	Mean and SD are reported. T-test or ANOVA was used to compare concentrations from in and out of the coal zone. Length-weight regressions were conducted for sculpins.
Archived Samples	not required
Advantages	new government requirement for industry to monitor a standard species for all individual mines
Disadvantages	opportunistic sampling by coal mines and BC MOE
Other Comments	Monitoring occurs under mine discharge permits, separately. The data began to be collected about 4 years ago. Data for the Elk Valley go back to 1998 but not regular monitoring. Typically for the new mines in the north-east they do analyses for all metals at the start, then the focus shifts to Se and % moisture. Final reports not available to the public yet.
References	Carmichael, M.B., and P.M. Chapman. 2006. http://wlapwww.gov.bc.ca/nor/pollution/environmental/water_quality/pdf/ selenium_sculpins.pdf
Contacts	N. Bruce Carmichael BC Ministry of Environment (250) 565-6455, Bruce.Carmichael@gov.bc.ca Peter M. Chapman Golder Associates (604) 904-4005, pmchapman@golder.com

Program	**Biological Survey of the North Saskatchewan River**
Region	SK
Study Proponent	SERM
Program Status	Completed
Years of Data	1985-1986
Sampling Frequency	annual
Overall Objectives	To examine mercury concentrations in fish from popular fishing locations on the North Saskatchewan River.
Number of Sampling Locations	3 sites; river
Reasons for Choosing Sampling Locations	angling locations
Study Design	survey
Contaminants	mercury
Effects Thesholds	**Human Consumption (SERM)** Hg 0 5 ug/g
Source of Guideline	SERM. 1999. (based on Health Canada)
Fish Species	GOLD, WALL, SAUG, NRPK
Total Sample Size	189 fish
Tissue Sampled	muscle
Amount of Tissue	n/a
Additional Fish Health Variables	length, weight, age, stomach contents, sex, maturity
Environmental Health Variables	creel survey, aerial survey to count anglers and other users
Sampling and Handling Methods	Gill nets were used to capture fish. Minnows and fingerlings were captured by seining along the shores and sandbars of the North Saskatchewan River and its tributaries. Minnow Traps and electro-shockers were also used but were ineffective in capturing small fish. Trap nets were also used. Fish were measured and weighed, and two ageing media were taken for laboratory analysis. Representative samples were frozen and the muscle tissue was sent to the Provincial Health Laboratory in Regina for mercury analysis. In 1985, 29 of the walleye and sauger were analyzed by the Saskatchewan Research Council for metal constituents.
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	n/a
Advantages	
Disadvantages	small scale program with a focus on mercury only
Other Comments	
References	Merkowsky 1987.
Contacts	Jennifer Merkowsky Saskatchewan Environment, Saskatoon Fisheries Laboratory (306) 933-7943

Program	**Dioxin and Furan Monitoring Program**
Region	BC, AB, SK, NB
Study Proponent	Health and Welfare, EC, DFO, Provincial Governments
Program Status	Completed
Years of Data	1987-1988
Sampling Frequency	annual
Overall Objectives	To determine whether dioxins were present in fish in the river and, if present, whether they may constitute a health hazard to humans.
Number of Sampling Locations	14 sites
Reasons for Choosing Sampling Locations	bleached kraft pulp and paper mills
Study Design	n/a
Contaminants	dioxins and furans, 2,3,7,8-TCDD, 2,3,7,8-TCDF, OCDD
Effects Thesholds	**Human Consumption (HC)** 2,3,7,8-TCDD 20 ppt
Source of Guideline	Health and Welfare Canada
Fish Species	(in SK) WHSC, WALL
Total Sample Size	n/a
Tissue Sampled	muscle, whole body (some)
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	Environment Canada, in cooperation with Saskatchewan Environment and Public Safety collected fish as part of a joint study in august 1988. Collected fish included river shiners, spottail shiners and fathead minnows. 2,3,7,8-TCDF was determined to be 2.8 ppt in shiners downstream on Prince Albert.
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	n/a
Advantages	canada-wide examination of dioxin and furan contamination at pulp mills
Disadvantages	short term study examining only dioxin and furan contaminantion from pulp mill effluents
Other Comments	Canada report not available at this time (EC 1988). Saskatchewan reports are short memo-style documents. No technical details available. This sampling program was part of national sampling program to analyze fish, water and sediments for dioxins from sites near 47 Canadian Pulp Mills. The program was coordinated by DFO, Environment and National Health and Welfare.
References	Environment Canada. 1988., Naftel, P.C. 1988., Naftel, P.C. 1989.
Contacts	

Program	**Mercury concentrations in fish in lakes in the Mackenzie River Basin**
Region	AB, NWT, SK
Study Proponent	EC, NCP, DFO
Program Status	Completed
Years of Data	1996-2000
Sampling Frequency	unknown
Overall Objectives	To examine mercury concentrations in fish from the Mackenzie River Basin. To examine the primary biological and chemical factors affecting higher mercury concentrations in fish. To consider how global warming and increased fishing pressures may affect mercury concentrations in fish.
Number of Sampling Locations	28 sites; lakes
Reasons for Choosing Sampling Locations	1996–2000 stock assessment studies by DFO
Study Design	compilation of data collected in individual studies
Contaminants	mercury
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	LKWH, LKTR, NRPK, WALL
Total Sample Size	not specified
Tissue Sampled	muscle
Amount of Tissue	0.2 g
Additional Fish Health Variables	length, weight, age, stable isotopes
Environmental Health Variables	limnology
Sampling and Handling Methods	Fish were caught in winter when the lakes were accessible by snowmobile and low temperatures provided a natural means of refrigeration for the large numbers of fish caught during these studies. Gill nets were set under ice. Fish were weighed, measured, and sexed in the field. Ageing structures (otoliths or scales from lake whitefish, lake trout, cisco and burbot; cleithra from northern pike; third dorsal spine from walleye) were removed from each fish. A few grams of dorsal muscle were removed, placed in a Whirl-Pak bag, and frozen for later analyses. Muscle tissue and structures used for age determinations were sent to DFO's Freshwater Institute (FWI), Winnipeg. Additional information on sampling procedures and detailed data are in Stewart et al. (2003a,b). Other lakes were sampled as part of studies specifically designed to assess mercury and/or persistent organochlorine contaminants in fish, i.e., Trout (2003), Stark (2003), Great Slave (1999 and 2000), Great Bear (2002), and Ste. Therese (2002).
Analytical Methods	Fish were shipped frozen and sent to the National Water Research Institute (NWRI), Saskatoon for whole body measurements and subsequent dissection of tissues for chemical analyses and aging structures. Mercury analyses were conducted on a 0.2 g tissue sample which was partially thawed and external surfaces cut away to yield the analytical sample. Samples were acid digested then measured by CVAAS.
Statistical Methods	n/a
Archived Samples	n/a
Advantages	provides mercury data for a number of lakes
Disadvantages	only mercury is reported
Other Comments	
References	Evans,et al. 2005.
Contacts	Marlene S. Evans National Research Centre, Environment Canada 11 Innovation Boulevard, Saskatoon, SK, S7N 3H5 (306) 975-5310, marlene.evans@ec.gc.ca

Program	**Environmental Effects Monitoring Program: Pulp and Paper, and Metal mining**
Region	Canada
Study Proponent	EC, DFO
Program Status	Ongoing
Years of Data	1992 - ongoing
Sampling Frequency	varies but can be up to every 3 years
Overall Objectives	To determine if industrial effluent has altered fish in such a way as to limit their use by humans. Includes altered appearance, altered flavour or odour, and contaminant levels that exceed human consumption guidelines or are statistically different from fish in a reference area
Number of Sampling Locations	sampling sites determined on a site specific basis
Reasons for Choosing Sampling Locations	appropriate reference area and an exposure area in the effluent plume
Study Design	control/impact
Contaminants	mercury, metals, dioxins, furans
Effects Thesholds	**Human Consumption (HC)** Hg 0.45 ug/g ww **EEM fish tissue effect threshold (EC)** dioxins/furans 15pg/g ww in muscle or 30pg/g ww in liver or hepatopancreas
Source of Guideline	Environment Canada. 2002., Environment Canada. 2005., Health and Welfare Canada
Fish Species	locally or commercially consumed
Total Sample Size	16 (8 from reference and 8 from exposure)
Tissue Sampled	edible portions or tissues most likely to estimate exposure and bioavailability of contaminants
Amount of Tissue	50 g (metals), 10 g composite (dioxin/furan)
Additional Fish Health Variables	length, weight, age, % lipid, % moisture, fecundity, egg size, gonad weight, liver weight, external condition
Environmental Health Variables	water quality, effluent quality, benthic community survey, sublethal toxicity
Sampling and Handling Methods	Samples must be of one species and if possible, samples should be of one sex and age class. If this isn't possible, then sex should be reported for each sample. Age classes should be consistent between areas. LETHAL: Metal analysis requires a 50g sample from one fish or a number of fish. Analysis of dioxins/furans requires a 10 g composite sample using equal tissues samples from 7-10 individuals. For finfish, edible portions (fillet) should be removed, skinned and deboned in the laboratory, with a hexane-rinsed, stainless steel knife and frozen in hexane-rinsed aluminium foil. ALTERNATIVE: extraction of fish muscle tissue using a non-destructive approach is based on the work of Baker (2002) and Baker et al. (2004). Two tools currently available for harvesting small tissue samples include dermal punches or the Tru-CutTM biopsy needle. Samples should be frozen using dry ice or liquid nitrogen to prevent decomposition during storage and transport to an analytical laboratory. If using non-lethal methods. fish must be anaesthetized. Tissue extraction. particularly the dermal punch.
Analytical Methods	Tissues should be kept frozen until analysis. Samples should be homogenized and a subsample taken for analysis. All dioxin/furan analyses be performed by HRGC/HRMS. Samples should be freeze dried and weighed prior to analysis.
Statistical Methods	Normal comparisons of reference and exposure can be made using t-test or ANOVA. Summary statistics should be included (max, min, mean, median, SD, SE) if possible.
Archived Samples	not required
Advantages	Standard methods recommended across Canada. Program is required under the Fisheries Act.
Disadvantages	Data only collected on a site-specific basis. Dioxins/furans measured for pulp mills that use chlorine in their processing. Mercury analysis is required if the mercury concentration in mine effluent is >0.1 ug/L. Other analyses may be requested on a site-specific basis.
Other Comments	Pulp and Paper: during Cycle 3, a total of 6 mills submitted fish tissue concentrations for furans and dioxins. Metal Mining: for Phase 1, 16 mines submitted fish tissue concentrations for mercury. Many other facilities have done analysis on site-specific contaminants of concern.
References	http://www.ec.gc.ca/eem/english/default.cfm Environment Canada. 2002., Environment Canada. 2005a., Environment Canada. 2005b.
Contacts	National Environmental Effects Monitoring Office Place Vincent Massey, 351 St. Joseph Blvd, 8th Fl Gatineau, Quebec, K1A 0H3 (819) 997-1535 EEM-ESEE@ec.gc.ca

Program	**Fraser River Action Plan: Resident Fish Contaminant and Health Assessment**
Region	BC
Study Proponent	EC, DFO
Program Status	Completed
Years of Data	1994-1996
Sampling Frequency	annual
Overall Objectives	To assess the condition of the basin based on contaminant levels, health and community structure.
Number of Sampling Locations	11 sites; rivers
Reasons for Choosing Sampling Locations	3 upstream reference sites; 4 sites d/s pulp mills and urban centres; 4 sites d/s in highly urbanized and intensive agriculture areas
Study Design	control/impact; survey
Contaminants	84 PCBs, 47 CPs, 24 Ocs, Ras, 15 dioxins and furans, PAHs, metals
Effects Thesholds	**Human Consumption (HC)** dioxin/furan TEQ 20 pg/g ww, PCB 2000 ng/g ww, DDT 5000 ng/g ww, Hg 0.5 ug/g ww, PAHs 1 - 4 ng/g ww (BC MOE), Se 3 ug/g ww (BC MOE), Toxaphene 5000 ng/g ww (USEPA) **Guidelines for the protection of terrestrial fish-eating wildlife (CCME)** TCDD 0.79 pg/g ww, 2,3,7,8-TCDD 0.71 pg/g ww, Toxaphene 6.3 ng/g ww, DDE 14 ng/g ww, DDE 1000 ng/g ww (IJC), Toxaphene 1000 ng/g ww (IJC) **BC criteria for fish tainting (BC MOE)** 4-Chloropheno 40 ug/g ww, 2,3-Dichlorophenol 80 ug/g ww, 2,4-Dichlorophenol 0.2 ug/g ww, 2,5-Dichlorophenol 20 ug/g ww, 2,6-Dichlorophenol 30 ug/g ww, 2,4,6-Trichlorophenol 50 ug/g ww, Pentachlorophenol 20 ug/g ww
Source of Guideline	CCME. 1999., BC MELP. 1998. (BC MOE), Brazner and De Vita. 1998. (IJC/US EPA)
Fish Species	PMCH, MNWH, STFL
Total Sample Size	~2476 fish
Tissue Sampled	muscle, liver, bile
Amount of Tissue	10 g muscle, 3-5 g liver
Additional Fish Health Variables	length, weight, age, lipid content, gonad weight (GSI), sex, maturity, internal abnormalities, tissue histology (organs)
Environmental Health Variables	water quality, sediment quality, terrestrial wildlife
Sampling and Handling Methods	Fish were collected with beach seines, bottom trawling, boat electroshocking, Gee traps, and hoop nets. Bodies were frozen on stainless steel trays, wrapped in plastic and aluminum. Gall bladders were stored in glass bottles and samples were frozen on dry ice until they were received by the analytical lab. Samples were stored in the lab at -15 C until analysed.
Analytical Methods	Five dorsal muscle samples were composited, up to 30 livers were composited and 5 or 30 bile samples were composited. Composite samples were created using equal proportions from each fish. Axys analytical measured PAHs, PCBs, OCs, CPs, RAs, dioxins/furans. Quanta Trace and National Laboratory for Environmental Testing measured metals. Dioxin/furan, CP, PAH, and RA analysis followed EC 1992 - GC/MS; PCB and pesticides - gas chromatography; PAH (bile) - HPLC; metals - ICP-AES (Quanta), AA Spec (NLET); Hg - CVAES (Quanta), CVAAS (NLET); As, Pb, Se - GFAES (Quanta); As, Se - ICP (NLET).
Statistical Methods	If at least one sample had a detectable level of the contaminant, the non-detects were recorded as 1/2 DL. If all samples below detection, then non-detects recorded as 0. For total PCBs: all non-detects were recorded as 1/2 DL.
Archived Samples	not specified
Advantages	extensive sampling program examining a large variety of chemicals
Disadvantages	program was not intended as a long-term monitoring program
Other Comments	
References	Raymond et al. 2001. http://www.rem.sfu.ca/FRAP/9820.pdf
Contacts	

Program	**Great Lakes Monitoring Program**
Region	ON
Study Proponent	DFO, EC, ON MOE
Program Status	Ongoing
Years of Data	1977- ongoing
Sampling Frequency	annual
Overall Objectives	To provide annual updates on contaminant trends in fish communities throughout the Great Lakes. The program can also use the contaminant burden data to identify emerging toxic chemical issues, and the toxicological significance and potential combined impacts of a range of toxic chemicals and their breakdown products.
Number of Sampling Locations	lakes
Reasons for Choosing Sampling Locations	All Great Lakes
Study Design	long term monitoring of trends
Contaminants	pesticides, PCBs, metals, mercury, CHL, mirex, dieldrin, toxaphene, PBDEs, BFRs, HBCD, PFOS
Effects Thesholds	**Human Consumption (GLSFATF)** PCBs 0.05-1.9 ppm, Hg 0.05-0.95 ppm, Chlordane 0.15-5.62 ppm, PCBs 0.153-1.22 ppm **(OMOE)** **USEPA wildlife protection value** PCB 0.16 ppm **GLWQA criteria** PCB 0.1 ppm, DDT 1.0 ppm, Hg 0.5 ppm
Source of Guideline	Great Lakes Sport Fish Advisory Task Force. 1993. (GLSFATF), Ontario Ministry of the Environment (OMOE). 2005., USEPA. 2004., IJC 1987. (GLWQA)
Fish Species	LKTR, WALL, RNSM, ALEW, sculpin
Total Sample Size	n/a
Tissue Sampled	whole body
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	invertebrates, water quality
Sampling and Handling Methods	Fish are collected at 10 sites annually, but the sites rotate among 4 sites on each Lake. Ontario sportfish monitoring program samples the Great Lakes as well. Methods are the same, or similar to US EPA program.
Analytical Methods	Whole fish are analyzed for PCBs, OCs, and Hg. A subset of samples are analyzed for non-routine contaminants (toxaphene, dioxins and furans, chemicals of emerging concern) by the EC Ultra-trace Laboratory at Burlington. DFO also measures a limited number of metals (As, Cu, Cd, Pb, Ni, and Zn) in selected forage fish.
Statistical Methods	n/a
Archived Samples	Yes - The Great Lakes Laboratory for Fisheries and Aquatic Sciences
Advantages	data is collected in conjunction with the US programs
Disadvantages	Intensity of sampling is limited by federal funding
Other Comments	EC is assuming DFOs monitoring role in this program.
References	http://www.dfo-mpo.gc.ca/regions/central/pub/bayfield/02_e.htm; Murphy et al. 2006. http://www.solecregistration.ca/documents/0121%20Contaminants%20in%20Whole%20Fish%20(SOLEC%202006).pdf; Hulting. 2005. http://www.great-lakes.net/pbtstrategyteam/documents/GLRC_PTS_WhitePaper_MonitoringSurveillance_Draftv1.pdf; Murphy et al. 2006. http://www.solecregistration.ca/documents/4201%20Contaminants%20in%20Sport%20Fish%20(SOLEC%202006).pdf
Contacts	Al Hayton Sportfish Contaminant Monitoring Program, Ontario Ministry of Environment (416) 327-7470, al.hayton@ontario.ca

Program	**Great Lakes Monitoring Program: Contaminants in Young-of-the-Year Spottail Shiners**
Region	ON
Study Proponent	OMOE
Program Status	Ongoing
Years of Data	1976 - ongoing
Sampling Frequency	annual
Overall Objectives	To assess the levels of persistent bioaccumulative toxic (PBT) chemicals in young-of-the-year spottail shiners. To infer local areas of elevated contaminant levels and potential harm to fish-eating wildlife. To monitor contaminant trends over time for the nearshore waters of the Great Lakes.
Number of Sampling Locations	15 sites; lakes
Reasons for Choosing Sampling Locations	All Great Lakes
Study Design	long term monitoring of trends
Contaminants	PCBs, DDT, DDD, DDE, CHL, Dioxins, Furans, HCB, HCH, Mirex, Octachlorostyrene
Effects Thesholds	**Guidelines and Criteria for the protection of terrestrial fish-eating wildlife** PCB 100ng/g (IJC), ΣDDT 14 ng/g (CCME), Chlordane 500 ng/g (Newell), Dioxin/furan 0.00071 ng/g (CCME), HCB 330 ng/g (Newell), HCH 100 ng/g (Newell), Mirex value below detection (IJC), Octachlorostyrene 20 ng/g (Newell)
Source of Guideline	IJC. 1998., CCME. 2001., Newell et al. 1987. (NYSDEC)
Fish Species	STSH
Total Sample Size	n/a
Tissue Sampled	n/a
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	n/a
Statistical Methods	When parameters were not detected, one half of the detection limit was used to calculate the mean concentration.
Archived Samples	n/a
Advantages	long-term program monitoring a large number of contaminants in forage fish
Disadvantages	Data is limited to one species of forage fish.
Other Comments	
References	Awad and Hayton. 2006. http://binational.net/solec/English/SOLEC%202004/Tagged%20PDFs/SOGL%202005%20Report/English%20Version/Individual%20Indicators/0114_Contaminants_in_YOY_Spottail_Shiners.pdf
Contacts	Al Hayton Sportfish Contaminant Monitoring Program, Ontario Ministry of Environment (416) 327-7470, al.hayton@ontario.ca

Program	**Liard River environmental quality monitoring program**
Region	NWT
Study Proponent	DIAND, GNWT, DFO, EC
Program Status	Completed
Years of Data	1992-1995
Sampling Frequency	annual
Overall Objectives	The Liard River Environmental Quality Monitoring Program was a comprehensive sampling program measuring the current condition of the Liard River at the boundary between British Columbia and the Northwest Territories. The Liard River Program measured important contaminants in water, suspended sediments and fish over a three-year period. The purpose of the Program was to assess the present status of the river, discover any hazards to human health or the aquatic environment, and to define a solid baseline to see if conditions change in the future.
Number of Sampling Locations	8 sites; river
Reasons for Choosing Sampling Locations	local fishing locations
Study Design	survey
Contaminants	metals, PCBs, PAH, dioxins, furans, 19 Ocs, 23 pesticides
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g commercial or 0.2 ug/g subsistence, OCs 0.1 ug/g, PCBs 2000 ng/g, 2,3,7,8-TCDD 20 pg/g **Guidelines for the protection of piscivorous wildlife (Nagpal, BC MOE)** PCBs 100 ng/g
Source of Guideline	Department of Health 1996., Health and Welfare Canada. 1998., Nagpal. 1992. (BC MOE)
Fish Species	MNWH, NRPK, WALL, LNSC, BURB
Total Sample Size	n/a
Tissue Sampled	muscle, bile, liver, whole body
Amount of Tissue	n/a
Additional Fish Health Variables	length, weight, liver weight, sex, maturity, age
Environmental Health Variables	water quality, sediment quality, river flow
Sampling and Handling Methods	Gill nets, set lines and angling were used to catch fish of sizes similar to those caught by the local fishers. Nets and set lines were generally set overnight and left in the water for 18-24 hours before they were checked and reset.
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	n/a
Advantages	large program for monitoring fish for contaminants of concern to human health
Disadvantages	program not designed as a long-term monitoring program
Other Comments	species and tissues analysed were revised continually over the course of the Program based on experience and results as they were obtained.
References	Taylor et al. 1998. http://nwt-tno.inac-ainc.gc.ca/pdf/wr/ Liard_River_Environmental_Quality_Monitoring_Program.pdf
Contacts	

Program	**Limnological study of selected lakes in the Lac de Gras area, Northwest Territories**
Region	NWT
Study Proponent	DFO, DIAND
Program Status	Completed
Years of Data	1994
Sampling Frequency	once
Overall Objectives	To provide baseline resource and contaminants information from undisturbed lakes in the Slave Geological Province.
Number of Sampling Locations	11 sites; lakes
Reasons for Choosing Sampling Locations	lakes in the Slave Geological Province
Study Design	survey
Contaminants	Metals, Ocs, PCBs, toxaphene, dioxins, furans, PAHs
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g commercial or 0.2 ug/g subsistence
Source of Guideline	Health and Welfare Canada. 1984.
Fish Species	LKTR, RNWH, ARGR
Total Sample Size	n/a
Tissue Sampled	muscle, liver, whole fish
Amount of Tissue	n/a
Additional Fish Health Variables	length, weight, liver weight, bile volume, sex, maturity, liver mixed function oxygenase enzyme activity, age, stomach contents
Environmental Health Variables	phytoplankton, chlorophyll, nutrients, thermal structure, benthic emergence, zooplankton biomass/composition, water quality
Sampling and Handling Methods	Fish were captured by angling, trap netting, gill netting, and electrofishing. Ten fish/species were collected for contaminant analysis. Fish were processed on site: livers, bile and muscle tissues were quick-frozen on dry ice. Tissues were kept on dry ice until arriving at the laboratory. Under-ice gill netting was also used to collect fish for contaminant analysis from Jan-March 1994. Fish collected at this time were frozen whole and sent to the Ecotoxicology Laboratory, DFO, in Burlington, Ontario for organochlorine analysis.
Analytical Methods	Samples were analysed at three labs. Cantest in Vancouver, BC: Samples for metal analysis were acid digested and tested using ICP. As, Cd, Pb, Ni used GFAAS, Hg used a Hg monitor and Cu and Zn used DFAAS. DFO lab in Winnipeg, MB: Hg was measured using CVAAS (acid digested); As, Se using Borohydride Reduction Method and AA Spec; Cu and Zn using air-acetylene flame AA Spec; Cd, Pb using GFAAS. Ecotoxicology Lab: OCs using GC/ECD; toxaphene using GC/ECD; PCBs using GC/ECD and GC/MS-SIM; dioxins and furans using carbon chromatography on an HPLC and GC/MS; PAHs using GC/MS
Statistical Methods	Except for PAHs, the detection limit was used for statistical analysis of values reported as less than detection. Dry weights were reported by the lab. Values were converted to wet weight prior to analysis.
Archived Samples	n/a
Advantages	Study provided baseline data for a variety of contaminants
Disadvantages	Single year study was not intended as a long-term monitoring program.
Other Comments	
References	Martin, K.A. 2001.
Contacts	

Program	**Manitoba Biomonitoring Program**
Region	MB
Study Proponent	MB DOE
Program Status	Completed
Years of Data	1978-1992
Sampling Frequency	annual
Overall Objectives	The objectives of the Biomonitoring Program were to determine the compositions and status of biotic communities, measure trace metal residues in fish muscle tissues and aquatic sediments, and measure chlorinated organic residues in fish muscle and aquatic sediments. To determine if fish were acceptable for human consumption.
Number of Sampling Locations	11 sites; rivers and lakes
Reasons for Choosing Sampling Locations	sites in the five major river basins in Manitoba
Study Design	survey
Contaminants	metals, OCs, PCBs
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g commercial
Source of Guideline	Health and Welfare Canada
Fish Species	WALL, BRBH, NRPK, WHSC, YLPR, SHRD, MOON, SAUG, SLRD, QUIL, CHCT, RCBS, CARP, BGBF, GOLD, FRDR, BURB, WHBS, BLCR
Total Sample Size	target: 10 fish per species per site
Tissue Sampled	Skinless, boneless muscle
Amount of Tissue	50-100g
Additional Fish Health Variables	Length, Weight, Sex, Maturity, Age
Environmental Health Variables	sediment and water quality in first few years
Sampling and Handling Methods	Gill nets, angling and seinging were used to collect fish. Appropriate ageing structures were collected and ages were determined by the Manitoba Department of Natural Resources, Fisheries Branch personnel according to procedures adapted from Lagler (1964). A skinless, boneless muscle tissue sample (fillet) approximately 50-100 g in size was removed from each fish and placed in an individual whirlpac bag, appropriately labeled and stored frozen.
Analytical Methods	Samples were submitted to the Environmental Sciences Centre (in Winnipeg) and analyzed for As, Cd, Cr, Cu, Pb, Ni, and Se content according to the techniques described by Sorba (1989). Hg analysis was based upon methods described by Hendzel and Jamieson (1976) and Environment Canada Analytical Methods (1979).
Statistical Methods	Temporal changes in Hg residues were compared by arithmetic annual mean values, annual linear regression estimates and ANCOVA. ANCOVA was performed on log transformed data with length as the covariate. Annual regression estimates were also calculated in order to try and minimize the effect of fish size on Hg content. Standardized Hg residues were calculated for predetermined fish fork lengths based upon multiplicative regression equations y=ln a (x)b.
Archived Samples	n/a
Advantages	large-scale program; data was incorporated into the sportfish consumption guide
Disadvantages	Only muscle collected because livers too small to analyze all metals and Ocs, and muscle is the usual portion of the fish to be consumed. Program discontinued.
Other Comments	Three of five reports reviewed: Reports are also available for Winnipeg River, and Saskatchewan River systems. Occasional monitoring conducted to update fish consumption advisories, but no reports available for this summary
References	www.manitoba.ca/waterstewardship Green and Beck. 1994, 1995, 1997.
Contacts	Dave Green Manitoba Water Stewardship (204) 945-0585

Program	**Mercury in fish from Northern Saskatchewan**
Region	SK
Study Proponent	SK Resources Branch
Program Status	Completed
Years of Data	1969-1976
Sampling Frequency	annual
Overall Objectives	To identify fish that contain Hg in muscle tissues, to indicate the levels of mercury in the various species, to describe the relationships between Hg content and size of fish, and to see if trends are evident in the Hg content since testing began
Number of Sampling Locations	208 sites; lakes
Reasons for Choosing Sampling Locations	not specified
Study Design	survey
Contaminants	mercury
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g
Source of Guideline	Health and Welfare Canada
Fish Species	CISC, GOLD, LKST, LKTR, LKWH, WHSC, NRPK, WALL
Total Sample Size	n/a
Tissue Sampled	muscle
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	Fish samples were from commercial fish samples, test net samples and gill nets
Analytical Methods	Analysis conducted at the Hazardous substance laboratory using the method of Hendzel and Jamieson (1976)
Statistical Methods	n/a
Archived Samples	n/a
Advantages	data was incorporated into the sportfish consumption guide
Disadvantages	program was discontinued
Other Comments	report not summarized in detail; data is included in the SK consumption guidelines
References	Murray 1978.
Contacts	

Program	**Mercury in Saskatchewan Fish: guidelines for consumption**
Region	SK
Study Proponent	SERM
Program Status	Ongoing
Years of Data	1968 - ongoing
Sampling Frequency	n/a
Overall Objectives	Identify sites of concern for human consumption of fish.
Number of Sampling Locations	401 sites; lakes and rivers
Reasons for Choosing Sampling Locations	The focus of sampling in southern Saskatchewan has been on popular angling areas and waters near known or suspected sources of mercury. In northern Saskatchewan, the monitoring program has included both commercial and sport-fishing waters.
Study Design	survey
Contaminants	mercury
Effects Thesholds	**Human Consumption** Hg 0.5 ug/g (safe) >1.5 ug/g Hg (not to be eaten)
Source of Guideline	Health and Welfare Canada., Ontario Ministry of Environment. 2005.
Fish Species	NRPK, WALL, YLPR, LKTR, LMBS, SAUG, GOLD, LKWH, BURB
Total Sample Size	n/a
Tissue Sampled	muscle
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	The provincial Contaminants-In-Fish Committee arranged sampling on recreational waters (collected by Saskatchewan Environment staff) and federal Fisheries and Oceans staff tested fish caught for commercial sale. Fish of different sizes were collected and analyzed to find the relationship of mercury level to fish length.
Analytical Methods	Fish collected by Saskatchewan Environment were analyzed at the Provincial Health Lab of Saskatchewan; Fish were collected and analyzed from commercially fished waters by Fisheries and Oceans staff
Statistical Methods	n/a
Archived Samples	n/a
Advantages	provides mercury consumption advice
Disadvantages	monitoring is not conducted regularly at this time, program was discontinued for a few years
Other Comments	
References	Saskatchwan Environment. 2004.
Contacts	

Program	**Mercury Monitoring Agreement, Northern Flood Agreement**
Region	MB
Study Proponent	MB DNR
Program Status	Completed
Years of Data	1983-1989
Sampling Frequency	annual
Overall Objectives	To monitor mercury in the Churchill River diversion poject as part of the northern flood agreement
Number of Sampling Locations	6 sites
Reasons for Choosing Sampling Locations	flood area
Study Design	survey/monitoring program
Contaminants	mercury
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g commercial
Source of Guideline	Health and Welfare Canada
Fish Species	LKWH, WALL, NRPK
Total Sample Size	n/a
Tissue Sampled	muscle
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	n/a
Advantages	data was incorporated into the sportfish consumption guide
Disadvantages	program discontinued
Other Comments	report not summarized in detail
References	Green. 1990.
Contacts	Dave Green Manitoba Water Stewardship (204) 945-0585

Program	**Metal concentrations in fish and sediments from lakes aux Dorés, Chibougamau, Obatogamau and Waconichi**
Region	QC
Study Proponent	QC MDDEP
Program Status	Ongoing
Years of Data	1998 - ongoing
Sampling Frequency	annual
Overall Objectives	To evaluate the contamination of fish in Lac Chibougamau, Lac aux Dorés, and Lac Waconichi. To identify the extent of the zone of contaminated sediments located downstream from mining industries (for Lac aux Dorés) and to confirm the metal levels contained in sediments in sectors located both close to and far from mines (for Lac Chibougamau). It also aims to describe the impacts of the mining industry, if any, as evidenced in sediments from Lac Waconichi (control lake) and the Obatogamau lakes. In addition, the study attempts to determine whether fish from the Obatogamau lakes show mercury levels that vary according to distance from mining activities.
Number of Sampling Locations	33 sites; lakes
Reasons for Choosing Sampling Locations	These lakes are used in particular by the Cree communities for sustenance fishing and by the residents of the James Bay Region and other Québec regions for sport fishing. There is mining activity near Lac Chibougamau and Lac aux Dorés. Obotagamau lake is downstream from the mining activity. Waconichi lake is a reference.
Study Design	control/multiple impact; long-term monitoring of trends
Contaminants	metals, PCBs, dioxins, furans
Effects Thesholds	**Human consumption (HC)** Hg 0.5 mg/kg, PCB 2000 ug/kg, dioxins/furans 15 ng/kg, As 3.5 mg/kg (CFIA), Pb 0.5 mg/kg (CFIA) **guidelines for the protection of terrestrial fish-eating wildlife (CCME/EPA)** Hg 0.033mg/kg, PCBs 160 ug/kg, dioxins and furans 0.66 ng/kg
Source of Guideline	CCME. 1999., Health and Welfare Canada. 1986., USEPA. 1995., CFIA. 2003.
Fish Species	LKTR, NRPK, WALL, LKWH, BURB, CISC, LNSC, LKCH, WHSC, NRWH
Total Sample Size	n/a
Tissue Sampled	muscle, whole body
Amount of Tissue	n/a
Additional Fish Health Variables	length, weight, age
Environmental Health Variables	sediments, mine tailing quality
Sampling and Handling Methods	Methods follow the Guide de normalisation des méthodes utilisées en faune aquatique au ministère de l'Environnement et de la Faune du Québec (Ministère de l'Environnement et de la Faune, 1994). Experimental mono-filament netting were used to sample fish.
Analytical Methods	Mercury analyses were conducted for individual walleye, northern pike, and lake trout, while other substance measurements were conducted only from homogenates classified by size and species. Concentrations were measured in wet weight (mg/kg for metals, µg/kg for PCBs, and ng/kg for dioxins and furans). Mercury was measured with ultraviolet photometry (LDC Milton Roy) and vapour formation. As and Se were measured by AA spec (Perkin-Elmer, model 603). The other metals were measured with ICAP and measured with a Jarrell-Ash spectrophotometer (model ICAP-9000). PCBs and dioxins and furans were measured with a high-resolution mass spectrophotometer.
Statistical Methods	Covariant analyses, using mercury and total length as variables, were carried out to compare mercury levels for lake trout, northern pike, and walleye in each fishing area. Prior to the analyses, the normality of residues was verified. To ensure the reliability of statistical tests, covariant non-parametric analyses were done. For each statistical analysis, the average levels were regarded as different when their probability was equal to or below 0.05. Each fish species was classified in three sizes according to the guide for freshwater sport fish consumption.
Archived Samples	not specified
Advantages	long-term program monitors several traditional contaminants in areas of known historical contamination
Disadvantages	Data is limited to traditional contaminants of concern.
Other Comments	
References	Laliberté and Tremblay. 2002. http://www.mddep.gouv.qc.ca/eau/eco_aqua/chibougamau/rapport-en.pdf Laliberté. 2004. http://www.mddep.gouv.qc.ca/eau/eco_aqua/chibougamau/2002-en.pdf
Contacts	Denis Laliberte Quebec ministry of the environment and wildlife (418) 521-3820 ext 4724

Program	**Metal concentrations in fish tissue from uncontaminated BC lakes**
Region	BC
Study Proponent	BC MOE
Program Status	Completed
Years of Data	1982-1987
Sampling Frequency	once
Overall Objectives	To provide baseline data for fish which can be compared to fish collected from other similar lakes as well as those lakes that may be contaminated.
Number of Sampling Locations	54 lakes
Reasons for Choosing Sampling Locations	uncontaminated sites
Study Design	survey; data compilation report
Contaminants	mercury, metals
Effects Thesholds	**Human Consumption** Hg 0.5 ug/g ww, Pb 0.8 ug/g ww
Source of Guideline	n/a
Fish Species	RNTR, CTTR, KKSL, SCSL, COSL, DVCH, LKTR, ARGR, MNWH, LKWH, NRPK, BURB
Total Sample Size	322
Tissue Sampled	muscle, liver, burbot liver
Amount of Tissue	n/a
Additional Fish Health Variables	weight, length, scales, age
Environmental Health Variables	n/a
Sampling and Handling Methods	Fish were sampled with gill nets. The goal was to collect up to 5 fish/species. Muscle and liver tissues were frozen in polyethylene cups until shipped to the lab.
Analytical Methods	Samples were analysed at the BC Ministry of Environment Lab. Liver samples were analyzed as individual samples or composites of samples from individual lakes. Tissue samples were acid digested. Hg was determined by CVAAS, Pb was determined by HGAAS and all other metals were determined by ICP-AES. Moisture content determined gravimetrically following homogenization and drying at 105°C.
Statistical Methods	Lab reported dry weight concentration: concentrations were converted to wet weight using % moisture prior to statistical analysis. Values below detection were recorded as the detection limit.Grand means were calculated for species and tissue type. Means were also calculated by biogeoclimactic zone and tectonic region. Data for sample sizes greater than 20 were tested for normality. The Wilcoxan rank sum test was used if data were not normal. Null hypothesis comparisons were based on genus. Least squares regression and logarithmic regression were used to determine bioaccumulation of metals. Metal concentrations were tested against weight and length. The kruskal-wallis test was used to compare metal concentrations within species occurring in different biogeoclimactic and tectonic regions. Mean values were also calculated by lake.
Archived Samples	n/a
Advantages	Provided baseline data for metals in a large number of lakes in BC.
Disadvantages	Storage of samples in polyethylene cups may have resulted in higher mercury concentrations due to absorption from air or other samples.
Other Comments	
References	Rieberger. 1992. http://www.env.gov.bc.ca/wat/ wq/reference/metalinfish.pdf
Contacts	

Program	**Northern River Basins Study**
Region	AB, NWT
Study Proponent	EC, AENV, GNWT
Program Status	Completed
Years of Data	1992-1994
Sampling Frequency	n/a
Overall Objectives	The study's objectives were to gather and interpret sound scientific information about the basins, develop appropriate recommendations for basin management, and communicate effectively with the public.
Number of Sampling Locations	n/a
Reasons for Choosing Sampling Locations	rivers in major northern watersheds
Study Design	baseline studies and compilation of reports
Contaminants	mercury, dioxins, furans, PCBs, CPs, OCs, RAs, metals, PCDD, PCDF
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 mg/kg, TCDD TEQ 20 pg/g ww, PCB 2000 ng/g, ΣDDT 5000 ng/g, other OCs 100 ng/g **Guidelines for the protection of terrestrial fish-eating wildlife (CCME/EC)** PCDD/F TEQ 1.1 pg/g ww **Guidelines for the protection of aquatic life** PCDD/F TEQ 18.2 pg/g lipid ww **(EC),** PCDD/F 50 pg/g lipid ww **(CCME)**
Source of Guideline	Health and Welfare Canada. 1995., Health and Welfare Canada. 1989., Environment Canada. 1995., CCME. 1995.
Fish Species	NRPK, MNWH, WALL, GOLD, LNSC, BURB, LKWH, WHSC, BLTR
Total Sample Size	n/a
Tissue Sampled	muscle, liver
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	n/a
Advantages	Data can be incorporated into provincial monitoring programs
Disadvantages	Composed of multiple individual studies that were not intended as long-term monitoring programs
Other Comments	
References	http://www.mb.ec.gc.ca/nature/ecosystems/ nrei-iern/dg00s11.en.html See Element II Report #23, #26, #46, #49 and #50
Contacts	Environment Canada (780) 951-8884 Alberta Environment (780) 427-3029

Program	**Northern Rivers Ecosystem Initiative**
Region	AB, NWT
Study Proponent	EC, AENV, GNWT
Program Status	Completed
Years of Data	1998-2003
Sampling Frequency	n/a
Overall Objectives	The five-year study focussed on priorities such as pollution prevention, endocrine disruption in fish, hydrology, contaminants, nutrients, safe drinking water and enhanced environmental monitoring. Its mission was to provide the scientific underpinning to the governments' response to the recommendations of the NRBS. Its goal was to provide an understanding of the impacts of development on the northern river ecosystems. Provide an assessment of the presence and quantity of contaminants in Slave River fish and delta sediments. Provide a status report on the state of the fish populations in Lake Athabasca, the Slave River and Great Slave Lake. Provide an assessment of endocrine disruption-causing substances, their existence, and their significane to fish reproduction.
Number of Sampling Locations	n/a
Reasons for Choosing Sampling Locations	rivers in major northern watersheds
Study Design	compilation of a number of reports conducted under the program
Contaminants	∑PCB, ∑DDT, ∑HCH, ∑CBz, ∑CHL, ∑Dioxins, ∑Furans, Toxaphene, Dieldrin, α-endosulfan, anisole/veratroles, mercury
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	BURB, BLTR, MNWH, LNSC, LKCH, LNDC
Total Sample Size	n/a
Tissue Sampled	muscle, liver
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	No
Advantages	Data can be incorporated into provincial monitoring programs
Disadvantages	Composed of multiple individual studies that were not intended as long-term monitoring programs. Studies designed to address issues identified in the NRBS.
Other Comments	
References	http://www.pnr-rpn.ec.gc.ca/nature/ ecosystems/nrei-iern/index.en.html See Element II Report #27 and #45
Contacts	Environment Canada (780) 951-8884 Alberta Environment (780) 427-3029

Program	**Northern Water Resource Studies**
Region	NWT
Study Proponent	DIAND, DFO
Program Status	Completed
Years of Data	1988-1990
Sampling Frequency	annual
Overall Objectives	To establish existing levels of contaminants in the Slave River, Hay river and Leland Lake
Number of Sampling Locations	3 sites; lakes and rivers
Reasons for Choosing Sampling Locations	not specified
Study Design	survey
Contaminants	mercury
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g ww commercial or 0.2 ug/g ww subsistence
Source of Guideline	Health and Welfare Canada
Fish Species	NRPK, WALL, LKWH
Total Sample Size	n/a
Tissue Sampled	muscle
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	n/a
Advantages	provided some baseline data for mercury
Disadvantages	short term study examining only mercury
Other Comments	Summary report on website. Full report not available at this time.
References	Grey et al. 1995. summary available at: http://www.ainc-inac.gc.ca/pr/pub/nwr/li5_e.html
Contacts	

Program	**Ontario Sportfish monitoring program**
Region	ON
Study Proponent	ON MOE, ON DNR
Program Status	Ongoing
Years of Data	1970 - ongoing
Sampling Frequency	annual monitoring (not all lakes); lakes retested every 1 to 10 years
Overall Objectives	Provide advice to consumers of sport caught fish to ensure that their health is not jeopardized from the consumption of sport fish.
Number of Sampling Locations	1700 sites; lakes and rivers
Reasons for Choosing Sampling Locations	popular angling areas; a known or suspected source of pollution nearby; major source of food for local inhabitants (usually lakes in the vicinity of First Nations' communities); It is being opened for recreational development; part of a monitoring program for long-term studies of contaminants in fish
Study Design	survey
Contaminants	mercury, metals, PCBs, dioxins, furans, mirex, photomirex, DDT, Toxaphene, lindane, heptachlor, aldrin, CHL, HCBs, octachlorostyrene, CPs, CBz, PAHs, BFRs, fluorinated surfactants, PCNs, dioxin-like PCBs
Effects Thesholds	**Human Consumption (HC)** Hg 0.26 ppm-0.52 ppm for women and children under 15; 0.61 - 1.84 ppm for general population, ΣPCB 0.153-1.22 ppm, Σdioxins and furans and dioxin-like PCBs 1.62-12.96 ppt, mirex 0.082-0.657 ppm, photomirex 0.015-0.122 ppm, toxaphene 0.235-1.877 ppm
Source of Guideline	Health and Welfare Canada
Fish Species	LNSC, MOON, NRPK, LKST, WALL, WHBS, WHCR, LKWH, WHPR, WHSC, YLPR, SPLA, CNSL, COSL, FWDR, GZSH, GOLD, LKTR, LMBS, SHRD, RCBS, RNWH, AMEL, ATSL, BLCR, BLUE, HSCS, BOWF, BKTR, BRBL, BNTR, BKTR, BURB, CARP, CHCT, PNSL, PUMP, QUIL, RNSM, RNTR, SAUG, SISC, SMBS
Total Sample Size	n/a
Tissue Sampled	muscle
Amount of Tissue	n/a
Additional Fish Health Variables	length, weight, sex
Environmental Health Variables	n/a
Sampling and Handling Methods	The fish are collected by staff from the Ministry of Natural Resources and the Ministry of the Environment using various methods. Whenever possible, the selection includes 10 or more fish of each species with lengths and weights representative of the size range of that species in the locations being tested. A boneless, skinless fillet of dorsal muscle flesh is removed from the fish, packaged and frozen for shipment to the Ministry of the Environment laboratory in Toronto.
Analytical Methods	Samples are sent to the Ministry of the Environment laboratory in Toronto where they are analyzed for a large variety of substances. Analysis conducted using CAEL approved methodology.
Statistical Methods	n/a
Archived Samples	No
Advantages	dynamic program that includes and extensive suite of chemicals and emerging contaminants of concern; Large number of species and sites spanning all of Ontario.
Disadvantages	
Other Comments	
References	Ontario Ministry of Environment. 2005. http://www.ene.gov.on.ca/envision/guide
Contacts	Al Hayton Sportfish Contaminant Monitoring Program, Ontario Ministry of Environment (416) 327-7470, al.hayton@ontario.ca\

Program	**Organochlorine contaminants in temporal trends (1992-2003) of three Yukon Lakes: focus on Lake Laberge**
Region	YK
Study Proponent	INAC, DFO, NCP
Program Status	ongoing
Years of Data	1992 - ongoing
Sampling Frequency	annual
Overall Objectives	Measure current OC contaminant levels in sentinel fish species in three Yukon lakes and examine temporal trends using data from previous studies.
Number of Sampling Locations	3 sites; lakes
Reasons for Choosing Sampling Locations	historic data availability, former commercial fisheries, local subsistence use
Study Design	survey
Contaminants	CHL, DDT, HCH, toxaphene, PCBs, CBzs
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	LKTR, BURB, INCO, NRPK, LKWH, LSCS, LNSC, RNWH, BRWH
Total Sample Size	~388 fish
Tissue Sampled	muscle, liver
Amount of Tissue	muscle (10-15g), 2.2g of liver
Additional Fish Health Variables	% lipid, length, weight, age, sex, stable isotopes
Environmental Health Variables	zooplankton, sediment chemistry, sediment core, phytoplankton, limnology
Sampling and Handling Methods	Fish were sampled using long line angling and small mesh index nets. Otoliths were used for ageing. Samples were wrapped in solvent washed foil and shipped frozen to the Freshwater Institute in Winnipeg for analysis. Sections of trout dorsal muscle and burbot livers were frozen and kept at –20 C prior to organochlorine analysis.
Analytical Methods	Fish muscle (10-15g) was homogenized with dry ice and mixed with 10g baked anhydrous sodium sulphate (600 C for 6hrs). The material was then mixed with baked hydromatrix and baked Ottawa sand in an extraction cell. A Dionex ASE300 was used with pesticide grade dichloromethane (DCM) and hexane (mixed 50:50) as the solvent. The solution was then mixed with sodium sulphate and allowed to settle for several hours. The extract was then reduced in a Rotovap and filtered through millipore filters followed by a DCM-hexane rinse. The extract was removed to calculate percent lipid content following drying. The remaining sample was processed with rinses of 50:50 DCM-hexane through manual gel permeation chromatography (GPC), containing Envirobeads (S-X3). The eluent was concentrated in a Rotovap and evaporated further under a stream of nitrogen for fractionation on a 1.2%-deactivated Florisil column. Burbot livers were extracted using the Ball Mill method. Approximately 2.2g of liver were added to a ball mill tube with baked sodium sulphate, hexane, and internal standard (PCB30-OCN) and a steel ball. The tubes were sealed and shaken for 15 minutes then allc Aldrin was used as a volume corrector prior to GC analysis.
Statistical Methods	OC data were log10 transformed prior to statistical analyses to normalize the distribution of the data. For each fish species within each lake, temporal differences in OC, condition factors and lipid content were tested using ANOVA (p =0.05) followed by Tukey's post-hoc test. OC concentrations were not adjusted using analysis of covariance (ANCOVA) because of heterogeneity of regression slopes indicating significant interactions of both log weights and lipid content with OC over time (across years). Relationships between OC concentrations and biological parameters including percent lipid, log10 weights, log10 lengths and log10 ages were analyzed using general linear multiple regressions (GLMR). Log length was removed from the models due to preliminary testing indicating a highly insignificant correlation with OC levels compared to either lipid or log weight. Regressions were run to determine the most influential factors on OC concentrations by fish species by lake within each year. Results are reported for the points where a factor other than lipid is a primary predictor of OC.
Archived Samples	n/a
Advantages	long-term data is available for the lakes in this study
Disadvantages	limited number of lakes and only traditional contaminants are monitored
Other Comments	2 relavant chapters from the thesis manuscript have been published (or are in preparation)
References	Ryan. 2005., Ryan et al. 2005a., Ryan et al. 2005b.
Contacts	Pat Roach Indian and Northern Affairs Canada 345-300 Main Street, Whitehorse, Yukon, Y1A 2B5 (867) 667-3139, roachp@inac.gc.ca

Program	**Organochlorines in Yukon Fish**
Region	YK
Study Proponent	INAC, NCP
Program Status	Completed
Years of Data	1991-1997
Sampling Frequency	annual
Overall Objectives	To determine organochlorine levels in Yukon fish
Number of Sampling Locations	34 sites
Reasons for Choosing Sampling Locations	Yukon First Nations recommended sampling locations and fish species, based on traditional use of fish and on community concerns. Additional lakes were chosen to provide broad geographical coverage.
Study Design	survey
Contaminants	OCs, Toxaphene
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	LKTR, BURB, LKWH, NRPK, ARGR, SCSL, CMSL, CNSL
Total Sample Size	n/a
Tissue Sampled	muscle, liver
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	Axys Analytical Laboratories in Sidney, B.C. and at the Department of Fisheries and Oceans laboratory in Winnipeg.
Statistical Methods	n/a
Archived Samples	n/a
Advantages	data provided for long-term trends of organochlorine contaminants in fish from a number of Yukon lakes
Disadvantages	Only traditional contaminants are reported. Project ended, but may be continuing under a different name by the Northern Contaminants Program
Other Comments	may be ongoing under a different name and funding program
References	Eamer and Palmer. 2004. http://www.emannorth.ca/ic/ds031/index.cfm
Contacts	Joan Eamer joan.eamer@ec.gc.ca

Program	**Persistent Organohalogen Contaminants in Fish from Lakes and Reservoirs in Southwestern British Columbia, Canada**
Region	BC
Study Proponent	EC
Program Status	Completed
Years of Data	1999-2002
Sampling Frequency	Once
Overall Objectives	This survey explored the extent and significance of POPs residues in south west British Columbia through the analysis of selected organochlorine compounds in: (1) fish tissues from remote lakes and reservoirs and, (2) high-elevation snowpack.
Number of Sampling Locations	17 sites; lakes and reservoirs
Reasons for Choosing Sampling Locations	wide range of physiographic conditions (elevation (0-1435m), watershed basin area/character, bathymetry)
Study Design	survey
Contaminants	84 PCBs, 26 OCs, Σtoxaphene, 10 CHBs, 41 PBDEs
Effects Thesholds	**Human Consumption (HC)** not specified **Guidelines for the protection of terrestrial fish-eating wildlife (CCME)** not specified
Source of Guideline	Health and Welfare Canada., CCME 1999.
Fish Species	RNTR, CTTR, DVCH
Total Sample Size	Total of 5-6 individuals of one dominant salmonid species (cutthroat trout, rainbow trout and Dolly Varden charr) from each of 17 lakes and reservoirs in SW BC were collected
Tissue Sampled	Skin-off muscle fillets
Amount of Tissue	n/a
Additional Fish Health Variables	age, weight
Environmental Health Variables	snow samples
Sampling and Handling Methods	Fish were collected using gill nets and angling. Samples were quick-frozen on site.
Analytical Methods	Analyses were done by Axys Analytical Services, Sidney, B.C. via GC/MS.
Statistical Methods	n/a
Archived Samples	Yes - Some are archived in Vancouver
Advantages	provided baseline data for a large number of chemicals in lakes in BC
Disadvantages	program was not intended as a long-term monitoring program
Other Comments	
References	Shaw and Gray, 2003 http://www.psat.wa.gov/Publications/03_proceedings/PAPERS/ORAL/1e_shaw.pdf
Contacts	Patrick Shaw Environment Canada, Pacific and Yukon Water Quality Monitoring (604) 664-4071

Program	**Slave River environmental quality monitoring program**
Region	NWT
Study Proponent	DIAND, GNWT, DFO, EC
Program Status	Completed
Years of Data	1990-1995
Sampling Frequency	annual
Overall Objectives	The program was designed to respond to the distinct requirements of two major monitoring goals. The first priority was to ascertain whether the fish in the Slave River were safe to eat. The second goal was to establish a baseline data set with which to compare future effects from upstream activities and long-range transport of contaminants.
Number of Sampling Locations	4 sites; lakes and rivers
Reasons for Choosing Sampling Locations	domestic fisheries locations (downstream of agriculture, oil sands development and pulp mills)
Study Design	survey with control/impact comparison
Contaminants	dioxins, furans, PCBs, PAHs, CPs, pesticides, metals
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g commercial or 0.2 ug/g subsistence, ΣDDT 5000 ng/g, dieldrin, endrin, lindane 100 ng/g, toxaphene 100 ng/g, PCB 2000 ng/g, 2,3,7,8-TCDD 20 ng/g, Pb 1000 ng/g **(USEPA)**
Source of Guideline	Health and Welfare Canada. 1984., Department of Health. 1996., USEPA. 1989.
Fish Species	LKWH, NRPK, BURB, WALL, LNSC
Total Sample Size	~470
Tissue Sampled	whole body, liver
Amount of Tissue	n/a
Additional Fish Health Variables	age, sex, length, weight, liver lipid concentration, body lipid concentration
Environmental Health Variables	water quality, TSS (not presented)
Sampling and Handling Methods	Detailed methods are available in Peddle et al (1997). Fish were collected using gill nets. All sample-processing instruments and equipment were washed and rinsed between samples with pesticide-grade solvents. Samples were placed in solvent-rinsed flint glass containers and sealed with a plastic cap, containing a full aluminum foil liner. All samples were stored at -20°C prior to analysis.
Analytical Methods	Samples were analysed at the Department of Fisheries and Oceans Ultratrace Laboratory in Burlington, Ontario (starting in 1988) and by Enviro-Test Laboratories (ETL) in Edmonton, Alberta (from 1990). Analysis of trace metals in fish tissue was conducted by CanTest Laboratories (CTL) in Vancouver, British Columbia. OC and PCB analyses (DFO) were performed with GC/ECD. Mirex and photo-mirex were measured with GC/MSD. The presence of a-HCH, y-HCH (lindane) and HCB was confirmed with the GC/MSD. Routine laboratory analytical QA procedures included spikes and recovery estimates plus duplicate analyses. Analytical data were corrected for spike recoveries. Dioxins and furans were analyzed with a GC/MS Concentrations of PAHs in fish tissue that were analyzed by Enviro-Test were measured using elutions. CPs were analyzed using a GC/SIM-MS. For analysis of heavy metals, fish tissue samples were acid digested. Hg analysis was performed using a 'Mercury Monitor'. Cd, Pb, As, and Ni levels were determined using a GFAAS. Cu and Zn were measured with DFAAS. All other elements were analysed using ICAP.
Statistical Methods	Where it was deemed feasible to conduct statistical analysis (when non-detect values represented 50% or less of the dataset), a 'sliding scale' model was used. The model suggests that if 40% of the data are non-detectable data points, then 0.6 of the number specifying the detection limit can be used. Based on this model, censored data in subsequent tables have been modified in this manner. The Spearman Rank Correlation Coefficient test was used to measure the association between two variables, while tests between two samples were conducted using the Mann-Whitney U test. Non-parametric analysis of variance was conducted using the Kruskal-Wallis test. Significance levels were set at P>0.05 or 95% probability of correct acceptance. Fish data were pooled and annual median concentrations of contaminants were then used in statistical analysis.
Archived Samples	n/a
Advantages	large program for monitoring fish for contaminants of concern to human health
Disadvantages	program not designed as a long-term monitoring program
Other Comments	Complete analytical results are detailed in Peddle et al. (1997)
References	McCarthy et al. 1997. http://nwt-tno.inac-ainc.gc.ca/pdf/wr/ Slave_River_Environmental_Quality_Monitoring_Program.pdf
Contacts	

Program	**Spatial and Long-term Trends in Persistent Organic Contaminants and Metals in Lake Trout and Burbot in Great Slave Lake, NT**
Region	NWT
Study Proponent	INAC, NCP
Program Status	Ongoing
Years of Data	1999 - ongoing
Sampling Frequency	annual
Overall Objectives	The first goal is to obtain the necessary time trend contaminant data to review the success of international controls in reducing contaminant inputs to the north. The second goal of the program is to provide early warning support for the assessment of new contaminants that may become a concern to human health and that could be considered for addition to international agreements.
Number of Sampling Locations	2 sites; lake
Reasons for Choosing Sampling Locations	two sites have been selected for this study because of the different pathways responsible for delivery of contaminants. The West Basin receives contaminants from both the Slave River and directly from the atmosphere and water circulation is relatively active. In contrast, the East Arm receives contaminants mostly from the direct atmospheric deposition and water circulation is relatively slow
Study Design	long term monitoring of trends
Contaminants	mercury, PCBs, DDT, toxaphene, BFRs, fluorinated organic compounds, chlorinated paraffins
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	LKTR, BURB
Total Sample Size	n/a
Tissue Sampled	liver
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	n/a
Statistical Methods	n/a
Archived Samples	n/a
Advantages	long-term monitoring to assess various contaminants of concern
Disadvantages	data limited to a single species in a single lake
Other Comments	The project will also examine regional differences in contaminant trends and, in particular, will compare results for burbot with those being gathered on the Mackenzie River at Fort Good Hope. In order to improve the study for future years the contaminants data from 1999-2004 for Great Slave Lake will undergo detailed interpretation.
References	Carrilo. 2005a. http://www.ainc-inac.gc.ca/ncp/summ0405/nt_e.html
Contacts	Gary Stern DFO, 501 University Crescent Winnipeg, Manitoba, R3T 2N6 (204) 984-6761, sterng@dfo-mpo.gc.ca

Program	**Spatial and Long-term Trends in Persistent Organic Contaminants and Metals in Temporal Trends Studies of Heavy Metals and Halogenated Organic Contaminants including New and Emerging Persistent Compounds, in Mackenzie River Burbot, Fort Good Hope, NWT**
Region	NWT
Study Proponent	DFO, NCP
Program Status	Ongoing
Years of Data	1999 - ongoing
Sampling Frequency	annual
Overall Objectives	The results from this study will aid in determining whether contaminant levels in burbot are increasing or decreasing. Results from this study will also help to assess whether international controls are effective at reducing levels of contaminants in the Arctic
Number of Sampling Locations	n/a
Reasons for Choosing Sampling Locations	human consumption concerns
Study Design	long term monitoring of trends
Contaminants	mercury, selenium, arsenic, PCBs, DDT, toxaphene, PCAs, PBBs, BDPEs, CDPEs
Effects Thesholds	n/a
Source of Guideline	n/a
Fish Species	BURB
Total Sample Size	n/a
Tissue Sampled	liver
Amount of Tissue	n/a
Additional Fish Health Variables	n/a
Environmental Health Variables	n/a
Sampling and Handling Methods	n/a
Analytical Methods	n/a
Statistical Methods	Results will be statistically compared to previous results and a suite of other biological parameters (such as size, age, etc) to assess temporal trends and the factors affecting those trends.
Archived Samples	n/a
Advantages	long-term monitoring to assess various contaminants of concern including new
Disadvantages	study limited to one species in one area of the River
Other Comments	summary based on the brief project summary for NCP
References	Carrilo, F. 2005b. http://www.ainc-inac.gc.ca/ncp/summ0405/nt_e.html
Contacts	Gary Stern DFO, 501 University Crescent Winnipeg, Manitoba, R3T 2N6 (204) 984-6761, sterng@dfo-mpo.gc.ca

Program	**Spatial and temporal trends of mercury and other metals in landlocked char from lakes in the Canadian Arctic archipelago**
Region	NU
Study Proponent	EC, NCP, INAC, AMAP
Program Status	Ongoing
Years of Data	1992 - ongoing
Sampling Frequency	annual
Overall Objectives	The objectives of this study were to compare concentrations of Hg, metals and POPs with older data from Amituk, Resolute and Char Lakes, in order to examine temporal trends as well as to investigate factors influencing contaminant levels in landlocked char such as trophic position, size and age, and climate.
Number of Sampling Locations	8 sites
Reasons for Choosing Sampling Locations	n/a
Study Design	long term monitoring of trends
Contaminants	mercury, metals, PCBs, OCs, BFRs
Effects Thesholds	**Human Consumption (HC)** Hg 0.2 ug/g ww subsistence
Source of Guideline	Health and Welfare Canada
Fish Species	ARCH
Total Sample Size	n/a
Tissue Sampled	n/a
Amount of Tissue	n/a
Additional Fish Health Variables	Length, weight, sex, diet
Environmental Health Variables	water temperature, climate
Sampling and Handling Methods	Fish were sampled using gill nets. Fish were dissected within 3–6 h of collection at laboratory facilities of the Polar Continental Shelf Project in Resolute.
Analytical Methods	Samples of liver, kidney and skin on dorsal muscle were frozen (-20 C) and then shipped to the National Water Research Institute (NWRI), Burlington, Ontario, and stored at -20 C until analysed. Otoliths were shipped to Dept of Fisheries and Oceans (Winnipeg) for aging. All analyses were performed by the National Laboratory for Environmental Testing (NLET) at NWRI, Burlington: samples were acid-digested. Hg was analysed by CVAAS, other metals were analysed with ICP-MS.
Statistical Methods	Non-detect concentrations were replaced with half the detection limit for calculation of arithmetic and geometric means and standard deviations. Results for each collection year were first tested for normality using skewness and kurtosis tests. Results for all elements were log10 transformed in order to reduce coefficients of skewness and kurtosis. ANCOVA was used to examine the effect of collection year, length, and age and their interactions on concentrations of major elements as well as to examine differences in mean concentrations among lakes. The general model that was evaluated was : [element]=lake+P +P*Lake, where P =length, weight or age. Temporal and spatial trend comparisons were conducted with fish N 200 g and b 1000 g in order to reduce lake*P interactions. Temporal trends for Hg and other elements were examined using ANCOVA and Tukey's post-hoc multiple means test on least squared mean concentrations.
Archived Samples	n/a
Advantages	long-term monitoring using a single species to assess various contaminants of concern, including emerging chemicals
Disadvantages	
Other Comments	plan is to collect 10-15 years of data
References	http://www.amap.no/ ; Muir et al. 2005.; Muir, Bright and Koch. 2000. http://pusnes.grida.no/amap/amappd/display_details.asp?ProjectID=90&org=1&Details=all ; http://www.ainc-inac.gc.ca/ncp/summ0405/nuvut_e.html
Contacts	Derek C.G. Muir National Water Research Institute, Environment Canada 867 Lakeshore Road, Burlington, ON, L7R4A6 (905) 319-6921, derek.muir@cciw.ca

Program	**Sportfish Monitoring Program**
Region	QC
Study Proponent	QC MDDEP
Program Status	Ongoing
Years of Data	1978 - ongoing
Sampling Frequency	annual collections, but not at all lakes
Overall Objectives	So that the population profits from the nutritive contributions of fish of sporting fishing all while being protected from the possible toxic effects of the contaminants present in the flesh of several species.
Number of Sampling Locations	849 sites; lakes and rivers
Reasons for Choosing Sampling Locations	fishing locations
Study Design	survey
Contaminants	mercury, PCBs, DDT, Mirex, Dioxins, Furans, HCB, dieldrin
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 mg/kg, PCB 2.0 mg/kg, DDT 5 mg/kg, Mirex 0.1 mg/kg, Dioxin/furan 15 ng/kg
Source of Guideline	Health and Welfare Canada
Fish Species	SMBS, BRBL, CHCT, MOON, ATHL, ATST, SAUG, RCBS, CISC, SHRD, SLRD, CARP, CHPC, WHPR, AMEL, LMBS, LNSC, WHSC, MUSK, GOLD, LKWH, WALL, RNSM, LKST, NRPK, ARCH, BKTR, ATSL, YLPR, ATTM, LKTR, RNTR, SPLA, SETR, OCPR, CNSL, FALL, GRCD, BURB
Total Sample Size	n/a
Tissue Sampled	skinless muscle
Amount of Tissue	100 g
Additional Fish Health Variables	length, weight, age
Environmental Health Variables	n/a
Sampling and Handling Methods	Angling, gill netting or electrofishing were used to collect fish. The objective is to collect five specimens per class of size (small, average, large), except in the case of the perch, for which the objective is nine specimens per class. For each specimen, approximately 100 grams of flesh are taken, if possible, from under the dorsal fin. The sample should not contain skin nor of internal organs. For the small specimens or small species, all the flesh is taken. The white suckers are preserved whole. Fish or tissues are wrapped in aluminium foil, are deposited in a polyethylene bag and are labelled. The samples must be frozen as soon as possible.
Analytical Methods	Samples are analysed at the Hydro-Quebec lab. The fish tissue homogenates are analyzed (composed of one or several fish) by size class and by species (three analyses per species). In particular cases, they will be analyzed individually in order to obtain more precise information by species, in particular when high concentrations are measured in certain size class homogenates.
Statistical Methods	n/a
Archived Samples	n/a
Advantages	large-scale program with data for a large number of lakes and species across Quebec; program is similar to the Ontario Sportfish monitoring program
Disadvantages	
Other Comments	document is only available in french threfore not all information is available for this summary
References	MDDEP. 2006. http://www.mddep.gouv.qc.ca/eau/guide/index.htm Audet. 2004. http://www.mddep.gouv.qc.ca/eau/eco_aqua/toxique/Protocole_echantillonnage.pdf
Contacts	Denis Laliberte Quebec ministry of the environment and wildlife (418) 521-3820 ext 4724

Program	**St. Lawrence Action Plan / St. Lawrence Vision 2000**
Region	QC
Study Proponent	EC
Program Status	Ongoing
Years of Data	1975, 1989
Sampling Frequency	infrequent
Overall Objectives	To assess the contaminant status of St. Lawrence River fish. The objective was to evaluate temporal changes and examine variation in contaminant levels, both among the three fluvial lakes and among fish species from different trophic levels, with the aim of identifying contaminant hot-spots and potential risks to human and aquatic health. (1) Our first goal was to assess the spatial variation in contaminant levels in different fish species by comparing among St. Lawrence River lakes and, between north and south within a given lake; (2) Since the last major survey of contaminants in St. Lawrence River fish (Sloterdijk, 1977) was conducted nearly 15 years ago, our second objective was to provide an update of the contaminant levels of St. Lawrence River fish, and, (3) Lastly, the extent of contamination in St. Lawrence River fish relative to those in fish from other contaminated (and pristine) water bodies was evaluated.
Number of Sampling Locations	12 sites, river lakes
Reasons for Choosing Sampling Locations	Within each lake, two sites were located on the northern side of the lake and two were located on the southern side in order to permit north/south comparisons of contaminant levels in fish. The lakes were chosen as sampling sites because of the socio-economic importance of their fisheries, and because of their tendency to serve as sinks or reservoirs for contaminants.
Study Design	historical data comparison, inter- and intra-lake comparison
Contaminants	9 metals, 9 CBzs, 19 OCs, PCBs, 16 PAHs
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g, HCB 0.1 ug/g, DDT 5 ug/g, lindane, aldrin, dieldrin 0.1 ug/g, heptachlor, heptachlor epoxide 0.1 ug/g, PCB 2 mg/g **Guidelines for the protection of fish-eating wildlife (IJC)** PCB 0.1 ug/g (whole fish), DDT 1.0 ug/g (whole fish), lindane, aldrin, dieldrin 0.3 ug/g, heptachlor, heptachlor epoxide 0.3 ug/g
Source of Guideline	Health and Welfare Canada., IJC. 1987.
Fish Species	BRBL, LKST, WHSC, YLPR, NRPK, WALL
Total Sample Size	203 fish
Tissue Sampled	muscle, whole fish, liver
Amount of Tissue	n/a
Additional Fish Health Variables	length, weight, age, lipid content, condition factor, sex
Environmental Health Variables	n/a
Sampling and Handling Methods	Sturgeon were bought from local fishers, while the other species were caught using either beach seines, gill nets, or electro-fishing. Not all fish species were collected at each site. Anatomical structures were removed for fish aging: opercula in perch and Walleye, cleithra in pike, pectoral spines in bullhead, and fin rays in sucker. Sturgeon were not aged. Individual fish were then wrapped in hexane-rinsed aluminum foil, labelled, and frozen at -20 C. In January 1990, fish were thawed and skinless fillets were removed. For approximately one-third of the fish, liver samples were also taken. In addition, 12 perch were chosen for whole body (minus the liver) analysis.
Analytical Methods	Samples were homogenized using a Polytron mechanical homogenizer. Two sub-samples of the homogenate were prepared. Homogenate samples intended for analysis of organic contaminants were stored in hexane-rinsed glass jars lined with foil; those to be analysed for metals were stored in nitric-acid-rinsed polypropylene containers. Samples were frozen at -20 C for a period not exceeding six months. Trace metal analyses were performed at Environment Canada's National Water Quality Laboratory in Burlington, Ontario. Organic contaminants were analysed at Novalab Ltd., a private laboratory located in Montreal. Hg was acid digested and analysed by a cold vapour AA spec. As and Se were analysed by AES using an ICAP-AES. Cd, Cr, Cu, Ni, Pb, and Zn were analysed by AA spec. CBzs, OCs, and PCBs were analysed via GC/ECD, while PAHs were analysed by HPLC with fluorescence detection.
Statistical Methods	For statistical treatment, contaminant concentrations below the LOD were assigned a value of one-half the LOD, except for the summed variables, for which values below the LOD were assigned a value of zero. In certain cases (As and heptachlor), where detection frequencies were low, values below the LOD were eliminated and statistical comparisons were performed on positive values only. Normality and homoscedasticity were verified using Hartley's Fmax test and the Shapiro-Wilk test, respectively (Sokal and Rohlf, 1981). All means presented for contaminant data are geometric means. Spatial differences in the morphometric characteristics of fish and in contaminant levels in muscle, liver, and whole tissue samples were tested using analysis of variance (ANOVA), analysis of covariance (ANCOVA), or t-tests. For the organic contaminants, statistical computations were performed on lipidnormalized data (i.e. contaminant concentration (wet weight) divided by percent lipid).
Archived Samples	n/a
Advantages	provided data for traditional contaminants
Disadvantages	infrequent program with no apparent routine sampling program
Other Comments	
References	http://www.qc.ec.gc.ca/CSL/pub/pub003_004_e.html ; Ion and de Lafontaine. 1998.
Contacts	

Program	**Mercury in edible muscle of fish from lakes in northern Canada**
Region	NWT, NU, YK, NL
Study Proponent	DFO
Program Status	Completed
Years of Data	1971-2001
Sampling Frequency	various frequencies
Overall Objectives	To determine if fish are safe to eat.
Number of Sampling Locations	209 sites, lakes
Reasons for Choosing Sampling Locations	all available sampling locations at the time of the analysis
Study Design	compilation of all fish data in the DFO Freshwater Institute database, Yukon contaminants committee database, and in additional government reports
Contaminants	mercury
Effects Thesholds	**Human Consumption (HC)** Hg 0.5 ug/g ww commercial or 0.2 ug/g ww subsistence
Source of Guideline	Health and Welfare Canada. 1979.
Fish Species	ARCH, ARGR, ATSL, BRWH, BKTR, BURB, CNSL, CMSL, CISC, DVCH, FRSC, GRTR, INCO, LKTR, LKWH, LSCS, LNSC, NRPK, PCHR, RNWH, WALL, WHSC, Whitefish, Sculpin, Sucker
Total Sample Size	7974 fish
Tissue Sampled	muscle
Amount of Tissue	0.2 - 1.0 g
Additional Fish Health Variables	length, weight, age
Environmental Health Variables	geologic formation (sedimentary, intrusive, volcanic, etc)
Sampling and Handling Methods	Fish samples were obtained from experimental netting, subsamples of commercial catch, research studies, fish stock studies, gill netting, angling and trap-netting.
Analytical Methods	Most of the samples were analyzed in the laboratories of the Freshwater Institute, Department of Fisheries and Oceans, in Winnipeg, Manitoba. Mercury samples were acid digested and analysed with CVAAS.
Statistical Methods	When duplicate samples of the same fish were analyzed, the mean of the duplicates was taken as the final result. The arithmetic means of concentrations of mercury in muscle and of fish lengths were calculated for each species. An effort was made to adjust mercury levels to a constant length by calculating the regression equation for (natural log) mercury on length. Some of the sites were sampled on two or more occasions over approximately 30 years. For comparisons of results from a single site sampled on different occasions, an analysis of covariance was used taking length as a covariate. In several instances, there were three or more different sampling times, and in those cases, if the effect of year of sampling was significant, the differences among pairs of sampling times were identified using the LSMEANS option of PROC GLM. In instances where the interaction between length and year was significant at $p = 0.05$, indicating that slopes of the regression lines were not parallel, no conclusion was reached regarding differences.
Archived Samples	n/a
Advantages	mercury data is available for a large number of sites and species
Disadvantages	only mercury is reported
Other Comments	
References	Lockhart et al. 2005.
Contacts	Gary Stern DFO, 501 University Crescent Winnipeg, Manitoba, R3T 2N6 (204) 984-6761, sterng@dfo-mpo.gc.ca

Program	**Monitoring Yukon Fish As Traditional Foods**
Region	YK
Study Proponent	NCP, DFO, INAC
Program Status	Ongoing
Years of Data	1992 - ongoing
Sampling Frequency	annual
Overall Objectives	To continue to assess long term trends and to maintain current data on levels of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic), organochlorine contaminants (e.g. PCBs, DDT, toxaphene) and new contaminants (e.g. brominated flame retardants, fluorinated organic compounds) in lake trout from Lakes Laberge and Kusawa. To provide additional information for use in updating health advisories.To investigate the fate and effects of contaminant deposition and transport to the Yukon, allowing Northerners to better manage the issue of contaminants.
Number of Sampling Locations	2 sites; lakes
Reasons for Choosing Sampling Locations	importance of trout to the subsistence diet of northerners the availability of current data sets and archived samples. Lakes Laberge and Kusawa were selected as the priority Yukon sampling location for long temp temporal trend studies
Study Design	long term monitoring of trends
Contaminants	PFOS, PFCAs, FTCAs, FTUCAs, Organohalogens, 40 OCs, 100 PCBs, 18 metals, mercury, BFRs, PBDEs, HBCD, DBDPE, BTBPE
Effects Thesholds	**Human Consumption (HC)** not specified
Source of Guideline	Health and Welfare Canada
Fish Species	LKTR
Total Sample Size	minimum 10 fish
Tissue Sampled	muscle, liver
Amount of Tissue	n/a
Additional Fish Health Variables	length, age, % lipid, sex, maturity, gonadal somatic indices, liver somatic indices, abnormalities, parasites
Environmental Health Variables	Freshwater mammals, Higher plants, Lichens, Mosses, Terrestrial birds, Terrestrial mammals
Sampling and Handling Methods	n/a
Analytical Methods	All analysis conducted at the Freshwater Institute in Winnipeg • 100 PCB congeners and organochlorine contaminants including toxaphene by high resolution mass spectrometry (FWI, Stern) • Mercury [cold vapour], 18 metals by ICP (FWI, Stern) • PDBEs DBDPE and BTBPE by GC low resolution mass spectrometry (FWI, Tomy) • HBCD and FOCs by LC tandem mass spectrometry (FWI, Tomy) • Stable isotopes (U of Winnipeg, Buhey)
Statistical Methods	ANCOVA was used to assess the effects of year to year collections (temporal trends), length and length*year interactions (homogeneity of the slope between length and [Hg]; univariate analyses will be performed with log10 transformed data to adjust for skewness. ANCOVA will be used to asses the effects of year of collection (temporal trends), biological parameters such as lipid content, size or age of the fish and BP*year interactions (homogeneity of slope between the different biological parameters and [contaminant]). Differences between the collection years will be examined with paired comparisons of BP adjusted least squared mean concentrations.
Archived Samples	Yes - DIAND freezers
Advantages	long-term monitoring program for lake trout in lakes that are important for fisheries
Disadvantages	
Other Comments	adding 5 additonal lakes over 5 years; the historic mercury data may be contained in "A history of total mercury in edible muscle of fish from lakes in northern Canada"
References	http://www.amap.no/ ; Stern, G. 2006., Carrilo, F. 2005c. http://www.ainc-inac.gc.ca/ncp/summ0405/yt_e.html
Contacts	Gary Stern DFO, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6 (204) 984-6761, sterng@dfo-mpo.gc.ca Pat Roach Indian and Northern Affairs Canada, 345-300 Main Street, Whitehorse, Yukon, Y1A 2B5 (867) 667-3139, roachp@inac.gc.ca

APPENDIX 2

SUMMARY OF 7 US FISH CONTAMINANT MONITORING PROGRAMS

Program Name:	**Great Lakes Fish Monitoring Program**
Official Program Acronym:	GLFMP
Region/Locations:	The Great Lakes: Superior, Michigan, Huron, Ontario, and Erie

Lead Agency:

U.S. Environmental Protection Agency's Great Lakes National Program Office (GLNPO) with significant involvement from US Food and Drug Administration (FDA), US Geological Survey-Biological Resources Division (USGS-BRD), and the eight Great Lakes States; The project is currently implemented by GLNPO with cooperation from the Great Lakes States, selected state agencies, and Native American Tribes.

Years of Data:

Mid-1960s started by the US Fish & Wildlife Service (the office involved is now the USGS-BRD), in 1977 GLNPO joined the program resulting in some modifications, in 1980 most of the remaining agencies joined the program resulting in further modifications. The program is on-going.

Frequency of Sampling:

Typically one of the two master sites per lake sampled in odd years and the other site in even years. Samples collected once per year between October and November for ELEMENT I and August and November for ELEMENT II (coinciding with salmon runs).

Overall Objectives:

To monitor temporal trends in bioaccumulative organic chemicals in the Great Lakes using top predator fish as biomonitors to assess potential human exposure to organic contaminants found in these fish. To provide information on new compounds of concern entering the lakes ecosystem.

The GLFMP goals are further subdivided:

ELEMENT I: Open Lake Trend Monitoring: The original intent of the open-lake trend monitoring element was to use changes in whole fish contaminant concentrations as an indicator of ecosystem trends (primary goal) and to evaluate the impacts of certain contaminants on fish health and fish population health.

ELEMENT II: Game Fish Fillet Monitoring: The objective is to evaluate human health risk and provide data necessary to develop sport fish consumption advisories.

Number of Sampling Sites:

10 sites in total: 2 for each lake, in open water areas of the 5 Great Lakes, all sites being in or near deep water.

Reasons for Choosing Sampling Locations:

ELEMENT I: LKTR and WALL sites represent both industrial and non-industrial areas in each of the lakes. In addition, sites were chosen to represent offshore fishing grounds (i.e., sampling sites should represent open water populations of fish) and are well removed from tributaries or other potential sources of contaminants.

ELEMENT II: COSL, CNSL and RNTR collection sites are based on historical collection by states for fish advisories. These sites are representative of human consumption.

Contaminants:

Pentachlorobenzene, Hexachlorobenzene, Octachlorostyrene, p,p-DDT, p,p-DDE, P,p-DDD, Heptachlor epoxide, Oxychlordane, Chlordane, Cis-nonachlor, Trans-nonachlor, Dieldrin, Endrin, Aldrin, Lindane, Mirex (L. Ontario only). Mercury and emerging contaminants, such as PBDEs were recently added to the list of contaminants to be analyzed. A scan for specified list of additional analytes, such as perfluorinated compounds, musk fragrances, APEs, pharmaceuticals and other personal care products (pseudo-persistence), other flame retardants, etc., will be conducted.

Program Name:	Great Lakes Fish Monitoring Program (continued)

Effects Thresholds/Source of Guideline:

ELEMENT I: Great Lakes Water Quality Agreement (GLWQA) criteria (whole fish) – three criteria are used, based on United States and Canada (1987): 1. For total PCBs (0.1 µg/g ww) for the protection of birds and animals which consume fish; 2. For DDT and metabolites (0.1 µg/g ww) for the protection of fish-consuming aquatic birds; and 3. For total mercury (0.5 µg/g ww) for the protection of aquatic life and fish-consuming birds). United States and Canada. 1987 http://www.ijc.org/rel/agree/quality.html

ELEMENT II: the Uniform Great Lakes Sport Fish Consumption Advisory (fillet, skin on) – the first (lowest concentration of contaminant) level of consumption restriction is based on concentrations of Chlordane (0.15 µg/g ww) and Total PCBs (0.153 µg/g ww) using the Great Lakes Sport Fish Advisory Task Force (1993) protocol. http://fn.cfs.purdue.edu/anglingindiana/HealthRisks/TaskForce.pdf

Fish Species:

ELEMENT I: top predator fish: LKTR collected from Lakes Superior, Michigan, Huron and Ontario; and WALL collected from Lake Erie.

ELEMENT II: COSL, CNSL collected from Lakes Michigan, Huron, Ontario, and Superior. RNTR collected from Lake Erie.

Type of Tissue Sample:

ELEMENT I: whole fish homogenates.

ELEMENT II: filet (skin on).

Total Sample Size:

ELEMENT I: 10 composite samples, representing 50 fish from each site.

ELEMENT II: 3 composite samples, representing 15 fish from each site.

Sampling and Handling Methods:

Collection nets must be free of any potential contaminants. Boat engine exhaust fumes must not reach the sample processing area. All sample storage containers must be cleaned with detergent and rinsed with distilled water. Clean nitrile gloves must be worn to handle fish and sample handling equipment. Fish are rinsed in ambient water and placed individually in separate clean holding containers to avoid any contamination from other fish, fuels, or other sources. Once killed the fish are wrapped in acetone-washed foil and immediately placed in polyethylene plastic bags cut to size (1 fish per bag). Once all the fish that meet the specifications for a composite are collected, they can be combined into one liner bag. For Element I. All fish must be whole and without incisions.

Extra Comments Re. Sample Collection:

On the day of collections fish can be kept on ice but subsequently all must be kept at ≤ -20°C until they reach the designated homogenization/processing laboratory. Fish retained for a composite sample must meet the following criteria: -All be of the same species,- Satisfy any legal requirements of harvestable size (or weight), or at least be of consumable size if no legal harvest requirements are in effect,-Be of similar size so that the smallest individual in a composite is no less than 75% of the total length of the largest individual, and be collected as close to the same time and location as possible, but no more than one week apart.

Amount of Tissue:

3 x 80 grams of the homogenate weighed separately into labelled 4-oz jars, providing there is sufficient sample. One of the 4-oz jars should be capped with a non-PTFE lid for future PFOS analysis. From each sample or composite at a sampling site, 30 grams are put into each of two 16-oz jars labelled as the working and the historical archive samples. These archives are subsamples of the sampling site and are usually used for investigative monitoring for new

Program Name:	Great Lakes Fish Monitoring Program (continued)

Contaminants. The jars are then placed in the freezer (approximately -20°C) to be kept for future use. Analyses are carried out on 2 g subsamples of homogenates.

Additional Variables Measured (Fish):

Species, sex of the fish, accurate Field Length and Total Maximum Length (in mm), Field Weight (g), fin clips, scales are collected for age analysis by carefully removing scales from the area between the dorsal fin and the lateral line.

Additional Variables Measured (Environmental Health):

Approximate water depth only. However there are other independent surveys and monitoring programs for further assessment of environmental health run by the same agency.

Emerging Contaminants Results:

There are a number of emerging contaminants reported in Great Lakes fish. The foremost is the group of brominated flame retardants (BFRs). Retrospective analyses of archived samples show continuing increase in concentrations of polychlorinated brominated diphenyl ethers (PBDEs) in LKTR from Lake Ontario. Concentrations have increased exponentially from 0.54 ng/g in 1988 to 190 ng/g wet weight, in whole fish samples, collected in 2002. One of the most widely used BFRs is hexabromocyclododecane (HBCD). Perfluoroctanesulfonate (PFOS) has also been detected in fish throughout the Great Lakes. PFOS is used in surfactants such as water repellent coatings (i.e., Scotchguard®) and fire suppressing foams).

Special Considerations:

Collection facilities must be able to retain frozen samples for at least 4 weeks, or until the US EPA-GLNPO Project Officer has specified a shipment date. All records and reports pertaining to sample collection should be sent to the GLFMP Project Officer, as soon as collection has been completed.

Statistical Considerations:

Because contaminant trends in each lake differ from one another, analyses were performed individually by site. Differences between means, variances, and trends between site pairs within a lake were evaluated.

Archives:

Tissue homogenate subsamples are archived at -20°C at USGS facilities.

Database:

The Great Lakes National Program Office (GLNPO) collects environmental data on a wide variety of constituents in water, biota, sediment, and air. Long after the studies are completed, the data remain and must be managed. Central to the data management effort is a computerized relational database system to house Lake Michigan Mass Balance and other project results. That system, the Great Lakes Environmental Database (GLENDA), was developed to provide data entry, storage, access and analysis capabilities to meet the needs of mass balance modellers and other potential users of Great Lakes data.

Pollution effects:

Some effects reported for Lake Michigan at least: -elevated levels of PCBs and dieldrin have led to fish consumption advisories and restrictions on commercial harvesting of walleye, carp, and salmon. Organic contaminants have led to reproductive impairments among fish-eating birds.

Advantages:

Long -term, on-going, and frequently reviewed program. Run by agency that is also actively involved in monitoring and studies of other environmental health parameters.

Program Name:	**Great Lakes Fish Monitoring Program (continued)**

Disadvantages:

The documentation of biological effects and determination of linkages between effects and exposure are not part of the GLFMP.

Web sites and References:

http://www.epa.gov/glnpo/glindicators/fishtoxics/fishc.html
http://www.ijc.org/rel/agree/quality.html
http://www.epa.gov/glnpo/glindicators/fishtoxics/GLFMP%20Review%20Document%206.14.05.pdf
http://www.solecregistration.ca/en/indicator_reports_contamination.asp
Hickey et al 2006
GLNPO 2005
http://nsdi.epa.gov/glnpo/glindicators/fishtoxics/GLFMP%20Review%20Document%206.14.05.pdf

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Program Name:	**National Lake Fish Tissue Study**, also referred to as: National Study of Chemical Residues in Lake Fish Tissue
Official Program Acronym:	NLFTS
Region/Locations:	Lakes and reservoirs in the lower 48 states (ie excluding the Great Lakes and the Great Salt Lake)

Lead Agency:

U.S. Environmental Protection. Part of the Agency's Persistent, Bioaccumulative and Toxic (PBT) Chemical Program.

Years of Data:

2000-2003 and 2005 may continue if funding becomes available.

Frequency of Sampling:

Each lake typically sampled once (sampling period up to 1 week long) in late summer/fall (but outside the spawning season of target fish species).

Overall Objectives:

To estimate the national distribution of selected persistent, bioaccumulative and toxic chemical residues in fish tissue from lakes and reservoirs in the lower 48 states. This four-year study will provide the first national estimates of mean concentrations for 268 chemicals in lake fish, define a national fish contamination baseline to track progress of pollution control activities, and identify areas where contaminant levels are high enough to warrant further investigation.

Number of Sampling Sites:

500 lakes and reservoirs in the lower 48 states. The lakes are at least 1 m in depth and divided into six size categories, ranging from 2.5 to over 900,000 surface acres, with a similar number of lakes in each category.

Reasons for Choosing Sampling Locations:

Lakes were randomly selected in 1999 from River Reach File 3 (RF3), which provided the best available GIS coverage for lakes and reservoirs at that time. RF3 contained over 270,000 lakes that could be potentially selected for the fish study. The Great Lakes and the Great Salt Lake were excluded from this set of lakes before initiating the lake selection process. The lake selection process was based on an unequal probability survey design.

Contaminants:

- Dioxins/furans: seventeen 2,3,7,8-substituted chlorinated dibenzo-p-dioxins and dibenzofurans (CDDs and CDFs)
- Total Mercury
- PCBs - 126 single PCB congeners, and another 33 results that represent co-eluting congener groups for the remaining 83 congeners, for a total of 159 PCB congener "results." In addition, each sample is associated with 10 values corresponding to the 10 possible levels of chlorination for the parent biphenyl
- Arsenic speciation including Total Inorganic Arsenic
- Organochlorine pesticides and total Aroclors
- Organophosphorus pesticides
- Semivolatile organics for further details see Categories of contaminants sheet

Effects Thresholds/Source of Guideline:

EPA Screening values (SVs) are used in this study for all target analytes except mercury. SVs are defined as concentrations of target analytes in fish tissue that are of potential public health concern and that are used as threshold values against which levels of contamination in similar

Program Name:	**National Lake Fish Tissue Study (continued)**

tissue collected from the ambient environment can be compared. Exceedances of these SVs should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted. The SVs are applied only to predator (fillets) samples not to the whole fish homogenates for bottom dwellers.
US EPA. 2000a http://www.epa.gov/waterscience/fishadvice/volume1/v1ch5.pdf
US EPA. 2000b http://www.epa.gov/waterscience/fishadvice/volume2/index.html#2
Fish tissue residue criterion (TRC) is used for mercury concentrations in tissue fillets. US EPA. 2001 http://www.epa.gov/waterscience/criteria/methylmercury/merc68.pdf

Fish Species:

1 predator/game fish species - recommended (in order of preference): LRBS, SMBS, BLCR, WHCR, WALL, YLPR, WHBS, NRPK, LKTR, BRTR, RNTR, BKTR; and 1 bottom dwelling species from each lake (in order of preference): CARP, CHCT, BLCT, BRBL, YLBL, WHSC. (US EPA 2000).

Type of Tissue Sample:

- •For predator composites: fillets both sides of each fish (skin-on, scales removed, with belly flap attached).
- •for bottom-dweller composites: whole fish homogenates (i.e., the entire specimen, including the head, skin, internal organs, muscle, and bones were thoroughly homogenized).

Total Sample Size:

Two fish composites per site (one composite of predators and another of bottom dwellers). Each composite comprised 5 adult fish of the same species and of similar size (so that the smallest individual within the composite is no less than 75% of the total length of the largest individual). Sample analyses required 560 grams of tissue homogenates.

Sampling and Handling Methods:

Clean nitrile gloves (provided by the sample control center) were worn during the entire sample handling process, beginning with removing the fish from the sampling gear. Fish were rinsed in ambient water to remove any foreign material from the external surface. Whole fish or fillets were individually wrapped in extra heavy-duty aluminum foil (provided by the sample control center as solvent-rinsed, oven-baked sheets). For specimens with sharp fins, spines were broken (*via* gloved hands or with the use of a tool covered with the aluminum foil provided by the sample control center) to prevent perforation of the wrapping materials. The broken section of the fins was included with the fish sample.

Extra Comments Re. Sample Collection:

- For predator fillets, the Sample Prep Lab used the entire fillet from both sides of each fish (skin-on, scales removed, with belly flap attached) instead of measuring and homogenizing equal weights of each fillet.
- For bottom feeders, each entire fish was homogenized and included in the composite instead of compositing equal weights of individually homogenized fish. Duplicate fish samples collected and analyzed from 10% of the lakes to provide an estimate of variability. The duplicate samples could be collected at the same time as the regular composite sample.

Amount of Tissue:

Composites consist of 5 adult fish of similar size that are large enough to provide 560 grams (20 ounces) of tissue for analysis of fillets for predators and whole bodies for bottom dwellers.3x100 mL of composite sample tissue homogenate (80% filled 125 mL jars).
Additional variables measured (Fish).
Species, Total Maximum Length (mm), Lab Weight (g).

Program Name:	**National Lake Fish Tissue Study (continued)**

Additional Variables Measured (Environmental Health):

pH, estimated maximum lake depth.

Emerging Contaminants Results:

PBDE concentrations in fish homogenates were analyzed in 2005 and the results are in the process of being compiled.

Special Considerations:

Statistical Considerations:

To control variability among tissue sample results, all samples collected during the study were analyzed by a single set of methods, and all analyses performed with a given method were performed by only one laboratory. Further control of variability was ensured by utilizing a single laboratory to prepare, composite, homogenize, and aliquot samples in a strictly controlled, contaminant-free environment.

Archives:

Tissue homogenate subsamples are archived at -20°C in a private laboratory (rented space).

Database:

Data CDs available from National Lake Fish Tissue Study, US EPA. All data generated during the study are being compiled in a centralized, custom-developed database designed for the following: eventual upload of results to the national STORET database system, statistical manipulation of results, export of results to user-friendly formats, and consistency in data format and nomenclature across laboratories and over time.

Pollution Effects:

Advantages:

Provides overview of the levels of pollution of lake fish throughout the 48 contiguous States.

Disadvantages:

No guaranteed funding for the continuation of this project.

Web sites and references:

http://epa.gov/waterscience/fishstudy
US EPA 2000 www.epa.gov/ost/fishadvice/volume1/index.html
US EPA 2002 www.epa.gov/waterscience/fishstudy/fieldplan.pdf
US EPA 2005 http://www.epa.gov/waterscience/fishstudy/nftsqareport-year1-4.pdf

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Program Name:	**National Water Quality Assessment Program**
Official Program Acronym:	NAQWA
Region/Locations:	Nation-wide streams and rivers Nation-wide

Lead Agency:

U.S. Geological Survey (USGS).

Years of Data:

1992 - 2001 monitoring continuing in a few study units.

Frequency of Sampling:

Samples collected during low flow conditions either in summer or autumn. Annually in some Study Units but only the data from one sampling event used in the National Survey.

Overall Objectives:

What is the condition of our Nation's streams, rivers, and ground water?
How are these conditions changing over time?
How do natural features and human activities affect these conditions, and where are those effects most pronounced?
Bed-Sediment and Tissue Studies are the primary means by which trace elements and hydrophobic organic contaminants are initially assessed in NAWQA. Concentrations and their spatial distribution are assessed to identify sources and potential needs for more detailed study. Data for bed sediment and tissue levels at common sites are used for an initial assessment of biological availability.

Number of Sampling Sites:

About 700 sites in 45 Study Units of the nation's major hydrologic basins. In each Study Unit there are 15-20 Occurrence Survey sites and, of these, between 7 and 13 are also water quality sampling sites. The number of Spatial Distribution Survey sites typically ranged from 20-30 (including the Occurrence Survey sites).

Reasons for Choice of Sampling Locations:

TWO Phases:

1. Occurrence Survey: Indicator sites are selected based on the highest likelihood of detecting contaminants: using data from water quality studies; where contamination is known to be probable; and selecting sites on stream that drain each major environmental setting. Integrator Sites are chosen to provide a coarse downstream network of sites where large-scale contaminant occurrences not detected at the Indicator Sites have a reasonable chance of being detected.
2. Spatial Distribution Survey: using the results from the Occurrence Survey, appropriate Indicator Sites are added to attain improved representation of the most important Environmental Settings and, furthermore, Integrator Sites are added to attain adequate spatial resolution in priority main-stem channels and major tributaries. Sites selected to minimize local scale spatial variability and to maximize comparability of data within and among Study Units.

Contaminants:

Occurrence Survey analytes: those known to be metabolized by fish (i.e. do not bioaccumulate) were excluded from fish tissue study.
Trace elements and major metals: Aluminum; Antimony; Arsenic; Barium; Beryllium; Boron (tissue only); Cadmium; Chromium; Cobalt; Copper; Iron; Lead; Manganese; Mercury; Molybdenum; Nickel; Selenium; Silver; Strontium; Thorium; Uranium; Vanadium; Zinc.
Organic contaminants: organochlorine insecticides and polychlorinated biphenyls: Aldrin; cis-chlordane; trans-chlordane; Dacthal; o,p'-DDD; p,p'-DDD; o,p'-DDE; p,p'-DDE; o,p'-DDT; p,p'-DDT; Dieldrin; Endrin; Heptachlor; Heptachlor epoxide; alpha-HCH; beta-HCH; delta-HCH;

Program Name:	**National Water Quality Assessment Program (continued)**

gamma-HCH (Lindane); Methoxychlor; o,p'; Methoxychlor, p,p'; Mirex; cis-Nonachlor; trans-Nonachlor; Oxychlordane; Polychlorinated biphenyls (PCBs-total); Toxaphene.
Other semivolatile organic contaminants: Hexachlorobenzene.

Effects Thresholds/Source of Guideline:

Benchmarks are for protection of fish-eating wildlife. When available, two benchmarks are used: $\text{Benchmark}_{\text{High}}$ - highest value in the range of wildlife benchmarks available for a given compound or group and $\text{Benchmark}_{\text{Low}}$ - lowest value in the range of wildlife benchmarks available for a given pesticide compound or group. The range of benchmark values was obtained from the following four sources: Oak Ridge NOAEL-equivalent concentrations in food (the lowest Cf value for piscivorous wildlife species from Sample and others, 1996); New York fish flesh criteria—non-cancer values (Newell and others, 1987); Canadian tissue residue guidelines (Canadian Council of Ministers of the Environment, 1999a, 1999b); proposed criteria from the U.S. Fish and Wildlife Service's report series, Contaminant Hazard Reviews (Eisler 1990).

Fish Species:

For tissue samples, one taxon generally was sampled at each site, although multiple taxa were collected at about 10 percent of sites. Fish taxa were selected from a National Target Taxa List (CARP, WHSC, LNSC, LRSC, CHCT, LRBS, BLGL, BKTR, BRTR), and the same taxon was sampled at as many sites as possible within the Study Unit. The most commonly sampled fish taxa were CARP and WHSC.

Type of Tissue Sample:

Whole fish homogenates for organic compounds and livers for trace elements.

Total Sample Size:

Fish samples were composites of 5-8 individual whole fish of similar size and all belonging to a single taxon.

Sampling and handling methods

Clean vinyl gloves were worn during the entire sample handling process. Fish were rinsed in ambient water.

For trace elements: body cavity opened using external dissecting tools, livers removed using internal dissecting tools, between 5 and 10 livers placed in a clean, tared glass jar capped with a teflon-lined cap. The sample is then weighed in the field and stored on dry ice.

For synthetic organic compounds: body cavity opened to determine maturity and sex, large fish wrapped individually in heavy duty aluminum foil (dull side facing the fish), for small fish all (5-8) can be wrapped together in the foil. The wrapped fish are then double bagged and put on dry ice. Kept at - 20°C until delivery to laboratory.

Extra Comments Re. Sample Collection:

All equipment (weighing pans, measuring boards, buckets, and containers) that come in contact with the fish to be submitted for organics analyses should be made of stainless steel that has been cleaned with a laboratory detergent, followed by copious rinsing with tap water, then rinsed with methanol (distilled in glass (DIG) or pesticide grade (GR), and allowed to air dry in a protected place. Field personnel are responsible for collecting hazardous-waste chemicals in approved containers and transporting these chemicals to the laboratory for proper disposal. Currently, no known source exists for supplying stainless steel measuring boards; therefore, plastic or wooden measuring boards, thoroughly cleaned with detergent, and distilled water, and rinsed with native water, will be substituted.

Amount of Tissue:

At least 5g of liver needed for trace element analyses, 10 g is optimal.

Program Name:	**National Water Quality Assessment Program (continued)**

Additional Variables Measured (Fish):

Field weight (g), total length (mm), maturity, sex, scales (or pectoral fin pine) for aging. For soft-rayed fishes, a scale sample of about 20 scales should be taken from the side of the fish, above the lateral line, and slightly anterior to the midpoint of the length of the fish. For spiny-rayed fishes, the scale sample should be taken from the area below the lateral line, near the tip of the oppressed pectoral fin. Any external anomalies. Anomalies are defined as the presence of externally visible skin or subcutaneous disorders or parasites. External anomalies include deformaties, eroded fins, lesions, tumours, diseases, and parasites.

Additional Variables Measured (Environmental Health):

Sediment data - collected at 600 of the 700 sites.

Emerging Contaminants Results:

A separate branch of USGS, the Biological Resources Division (BRD) deals with emerging contaminants under the Contaminant Biology Program. Disruption of endocrine function in fish is being actively researched. http://www.ecrc.usgs.gov/endocrine/summary.htm

Special Considerations:

Chlorinated dioxins and furans were analyzed only at selected sites (for example, near potential sources, such as pulp and paper mills, for which existing data were not available).
For comparisons of non-detection of contaminants the method detection limits for groups of contaminants were "censored" to compare the same concentrations of contaminants.

Statistical Considerations:

For the national statistics not all samples were used. Only one sample from each site was used. At the majority of sites, only one fish sample was available. If multiple samples were available for a given site the one representing the most commonly collected taxon, and collected earliest in the study, was selected for national analysis. This prevented multiple-year or replicate samples from weighting statistics towards certain sites.

Archives:

Fish tissue homogenates stored in a standard freezer together with set blanks and set spikes.

Database:

USGS NAWQA Data Warehouse - online, free and searchable database.
http://water.usgs.gov/nawqa/data

Pollution Effects:

Organochlorine pesticides that are no longer used, such as chlordane, dieldrin, and DDT. Concentrations in whole fish exceeded guidelines for the protection of fish-eating wildlife at about 20 percent of all sampled sites.
Polychlorinated biphenyls (PCBs) used until the 1970s for insulation in transformers and capacitors and as a lubricant in gas pipeline systems -- Concentrations exceeded guidelines for the protection of fish-eating wildlife at more than 30 percent of all sites.

Advantages:

Wide variety of parameters measured including water quality and sediments. Design of study allows making connections between land use categories and likelihood of contaminant problems of water ways. Because each Study-Unit assessment adheres to a nationally consistent sampling and analytical methodology, water-quality conditions in a specific locality or watershed can be compared to those in other geographic regions. Collectively, the assessments advance an understanding of the quality of water across regions and the Nation. Information at different scales helps to bridge local, state, regional and national efforts to manage the Nation's water resources.

Program Name:	**National Water Quality Assessment Program (continued)**

Disadvantages:

The post 2001 fish tissue sampling continues in only a few of the Study Units.

Web sites and References:

http://ca.water.usgs.gov/pnsp/
http://ca.water.usgs.gov/pnsp/oc_doc.html#Tables
Gilliom et al 1995
http://pubs.usgs.gov/circ/circ1112/sediment_tissue.html
Nowell and Crawford 2003
http://ca.water.usgs.gov/pnsp/oc_doc.html
Crawford and Luoma 1992
http://pubs.er.usgs.gov/usgspubs/ofr/ofr92494

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Program Name:	**Biomonitoring of Environmental Status and Trends: Large River Monitoring Network**
Official Program Acronym:	BEST: LRMN
Region/Locations:	Large inter-jurisdictional rivers of U.S, including the Mississippi, Columbia, Rio Grande, Yukon, Colorado, Pee Dee, Apalachicola, Savanna, and Mobile Rivers (more being added). This summary focuses on Columbia River Basin study.

Lead Agency:

U.S. Geological Survey (USGS)

Years of Data:

1995 – on-going
(evolved from the NCBP 1969-1985)

Frequency of Sampling:

Samples collected annually, usually either during fall or spring

Overall Objectives:

1. Provide a coarse resolution of the distribution of contaminants and effects in large rivers of the country.
2. Assess if contaminants in fish, and their effects, are changing over long time scales.
3. Provide critical comparative and interpretive information for scientist conducting site-specific investigations; information that is currently lacking with most of the biological effect measures.
4. Identify topics to be addressed through synthesis and applied research within BEST and to guide follow-up investigations and research.

Number of Sampling Sites:

117 sites ranging from about 10 to 48 per river basin Columbia River: 16 sites.

Reasons for Choice of Sampling Locations:

Initial sampling sites were chosen from established monitoring sites from preceding (NCBP-National Contaminant Biomonitoring Program) and other water monitoring programs (NAWQA and NASQAN -National Stream Quality Accounting Network). Beginning in 2004, sampling designs were modified to incorporate a random sampling design. Since that time, sampling designs applied to the Colorado, Pee Dee, Apalachicola, Savanna, and Mobile Rivers incorporated probability based site selection. During 2006, sampling will occur in the Potomac, Delaware, and the Susquehana Rivers. This sampling effort will also use a probability based design for site selection.

Contaminants:

- Trace elements and major metals: Arsenic; Cadmium; Chromium; Copper; Lead; Mercury; Nickel; Selenium; Zinc;
- Organic contaminants: cis-chlordane; trans-chlordane; o,p'-DDD; p,p'-DDD (TDE); o,p'-DDE; p,p'-DDE; o,p'-DDT; p,p'-DDT; Dieldrin; Endrin; Heptachlor epoxide; alpha-HCH; beta-HCH; gamma-HCH (Lindane; Mirex; cis-Nonachlor; trans-Nonachlor; Oxychlordane; (PCBs-total); Toxaphene; Hexachlorobenzene (HCB);
- EROD activity (liver sample) - sensitive to PAHs, chlorinated dioxins and furans, and PHHs such as PCBs;
- Macrophage aggregate analysis (spleen subsample) - sensitive to multiple contaminants including PAHs and metals;
- H4IIE bioassay (whole fish homogenates) - sensitive to PCBs, chlorinated dioxins and furans; and
- Vitellogenin (blood plasma sample) - sensitive to endocrine-modulating substances.

Program Name:	Biomonitoring of Environmental Status and Trends: Large River Monitoring Network (continued)

Effects Thresholds/Source of Guideline:

The BEST programme refers to numerous effects thresholds/criteria/guidelines for the various contaminants detected in the study. The effects of concern are for health of predatory fish and piscivorous wildlife (typically birds). The effect threshold values provided in Jarvinen and Ankley (1999), and in the series of specific substance reviews by Eisler, are used for most of the detected contaminants. Specifically: Jarvinen and Ankley (1999) for As, Cu, Cd, Cr, Hg, Ni, Pb, Zn, dieldrin, toxaphane, p,p'DDE; Eisler (1990) for Chlordane; Eisler and Jacknow (1985) for toxaphane; Newell et al (1987) for PCBs and p,p'DDE; and Barr (1986) for Hg.

Fish Species:

Actual fish species targeted depend on actual river basin but chosen to maintain comparability with previous and other monitoring programs.

e.g. In Columbia River, the targeted species were:

- bottom dwelling - CARP
- predator species- LRBS

These accounted for 80% of fish sampled, total of 8 spp were collected.

Type of Tissue Sample:

For both predator and bottom-dwelling species:

whole fish homogenates for organic compounds and livers for trace elements (less portions of gonad, kidney, spleen and liver removed for other analyses, and less any tissue anomalies which were removed for histopathology)

Total Sample Size:

Ten of each, adult male and female composites of each species were collected for a total of 40 fish per site. Each composite comprised fish of similar size, same sex and species.

More than 2 species of fish were collected at sites where insufficient numbers of preferred target species were caught.

Sampling and Handling Methods:

Clean vinyl gloves worn during the entire sample handling process:

1. fish are secured (electrofishing preferred) and held alive in ambient water, 2. blood is collected 3. eyes and head surface examined 4. fish is subdued weighed and measured, 5. put (alive) on wet ice, body surface and gills examined for lesions and other anomalies (excised and preserved in fixative), 6. abdominal cavity opened and viscera removed, excluding kidneys, 7. internal examination and collection of subsamples, 8. Collection of spines and scales for aging the fish 9. preparation of carcass samples

Extra Comments Re. Sample Collection:

Amount of Tissue:

Minimum 130 g homogenate for each composite sample (100g subsample for elemental contaminants, 10 g for H4IIE bioassay, 10 g for GC-ECD determination of organochlorines).

Additional Variables Measured (Fish):

- Total length (mm) and weight (g);
- Histopathology (samples of liver, gill, gonads, spleen and kidney) microscopic examination for the presence of lesions - can provide early indication of chemical exposure;
- Somatic indices (relative mass of gonads spleen and liver);
- Visual assessment of external and internal anomalies such as lesions, parasites and tumours; and
- Scales or spines collected for age determination.

Program Name:	**Biomonitoring of Environmental Status and Trends: Large River Monitoring Network (continued)**

Additional Variables Measured (Environmental Health):

None

Emerging Contaminants Results:

In a number of sites of the Columbia River basin feminization of fish was observed. BEST is also investigating the effects of pharmaceuticals and personal care products associated with wastewater treatment plants. This work is being done through collaboration between the BEST project and the USGS Toxics Program (Emerging Contaminants Project) and the USGS National Water Quality Lab. Details of the program should become available in the near future.

Special Considerations:

Statistical Considerations:

Species were grouped into larger taxon groupings for analysis. These included CARP, LRSC, bass, NRPM, RNTR, and WALL. For indicators based on individual fish (biomarkers and age) data are discussed in terms of the magnitudes of the means or medians for combined stages or each stage within a gender for different species or taxon grouping.

Archives:

Fish tissue homogenates, histological samples of tumours and tissue anomalies, otoliths, spines and scales are all archived.

Database:

BEST Large River Fish Health Data Query Tool: This is an interactive database that includes fish health data from the BEST Programs large river monitoring activities. Online at: http://www.cerc.usgs.gov/data/best/search/index.htm.

Pollution Effects:

Lead, mercury and selenium fish tissue concentrations exceeded protective criteria at several stations downstream from a smelting complex. Mercury exceeded the wildlife threshold effect values at various sites throughout the Columbia River basin. Guidelines for PBCs and p,p'-DDEs were also exceeded at several sites. The biomarker responses (EROD and H4IIE bioassay) were consistent with contaminant exposure of fish at specific locations within the Columbia River Basin.

Advantages:

Continues monitoring for fish tissue contaminants of some old NAWQA sites and other historical national fish tissue monitoring sites, thus allowing for temporal trend analyses. Using EROD activity (sensitive to all: PCBs, PCDDs & PCDFs, PAHs), H4IIE bioassay (sensitive to PCBs, PCDDs & PCDFs) and analysis for PCBs using gas chromatography with electron-capture detection (GC-ECD) allowed for the estimation of the relative concentrations for potential biological effects of these contaminants without the expense of instrumental analyses of their concentrations. Symptom (vitellogenin production and feminization) based detection of presence of endocrine disruptors in the water. Best overall assessment of fish and environmental health.

Disadvantages:

Fish processing in the field requires specifically trained personnel, the use of liquid nitrogen (for EROD liver samples), and about 20 minutes processing time per fish. Fish were held in live wells for processing, at some stations overnight, in tanks or net pens containing ambient river water following night collections (greater field effort).

Program Name:	**Biomonitoring of Environmental Status and Trends: Large River Monitoring Network (continued)**

Web sites and References:

http://www.best.usgs.gov/bestprojects.html
http://www.best.usgs.gov/index.html
Schmitt et al 1999 http://www.cerc.usgs.gov/pubs/BEST/field_BEST.htm
Schmitt et al 2000 http://www.cerc.usgs.gov/pubs/BEST/methods.pdf
Hinck et al 2004

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Program Name:	**Regional Ambient Fish Tissue Monitoring Program**
Official Program Acronym:	RAFT
Region/Locations:	River and lake monitoring in Iowa and Missouri, including border sites on the Mississippi River (focus on Iowa Program)

Lead Agency:

Iowa Department of Natural Resources.

Years of Data:

1983 - on going for Status and Follow up sites.
1994 - ongoing for Trend sites.

Frequency of Sampling:

THREE types of sites:

1. Status sites - samples collected each year from different water bodies or different locations in the same water bodies. Individual sites re-sampled every 5 years for rivers and every 10 years for lakes.
2. Follow-up sites - status sites, re-sampled the following year, where concentrations of contaminants in fish tissue exceeded state advisory guidelines.
3. Trend sampling sites are permanent: half are sampled in the odd years and half in the even years.

Overall Objectives:

To monitor contaminants in the environment, partly, but not exclusively, for assessing risk to human health.

Number of Sampling Sites:

10 permanent Trend Sites in Iowa (5 sampled each year)
20 Status and 7 Follow up sites in 2005 (vary from year to year).
Changes in 2006: all trend sites will be sampled in even-numbered years (i.e., 2006, 2008, 2010, etc.). The purpose of this change is to free-up sampling resources in the odd-numbered years to allow region-wide sampling of other water resource types (e.g., small (non-priority) lakes and urban lakes).

Reasons for Choice of Sampling Locations:

The majority of RAFT sites sampled each year determine whether the water bodies meet the "fish consumption" portion of the fishable goal of the federal Clean Water Act. In other words, these sites are used to screen for contamination problems and to determine the water quality "status" of the water bodies (Status sites). In cooperation with US EPA Region 7 and other Region 7 States, river sites were selected that would be monitored every other year to determine trends in levels of contamination (Trend sites).

Contaminants:

PCB-Aroclor 1248; PCB-Aroclor 1254; PCB-Aroclor 1260; chlordane, technical; chlordane, cis-; chlordane, trans-; nonachlor, cis-; nonachlor, trans-; DDD, 4,4'-; DDE, 4,4'-; DDT, 4,4'-; oxychlordane; heptachlor; dieldrin; heptachlor epoxide; hexachlorobenzene; BHC (lindane); cadmium; lead; mercury; selenium; trifluralin; mirex; Diazinon; 1,2,4,5-tetrachlorobenzene; pentachloroanisole; pentachlorobenzene.

Effects Thresholds/Source of Guideline:

To determine the "follow up" sampling sites, the "IDNR level of concern" benchmarks are used. For other purposes guidelines for Human Consumption are used: IDNR/Iowa Department of Public Health (IDPH) advisory levels, FDA levels of concern and FDA action levels. These were all developed by Iowa Department of Health.

Program Name:	**Regional Ambient Fish Tissue Monitoring Program (continued)**

Fish Species:

Status sites: 1 predator fish species: LRBS, SMBS, crappie, WALL, NRPK, etc.
and 1 omnivorous bottom dwelling species: CHCT and CARP are the preferred species
Trend sites: CARP

Type of Tissue Sample:

Status and Follow up sites: skinless fillet;
Trend sites: whole fish homogenates.

Total Sample Size:

Composites of 3 to 5 (similar size fish of the same species) for each the skinless fillets and the whole fish homogenates.

Sampling and Handling Methods:

For skinless fillets: skin should be removed from fillets from all species. Fish can be filleted either in the field or at an IDNR fisheries office. If fish will be transported to the office for cleaning, they should be transported on wet ice in clean coolers. Surfaces on which the fish are filleted (cleaning boards) should be covered with extra heavy duty aluminum foil; this foil should be changed for each new composite sample. Fillet knives and other instruments used to clean the fish should be cleaned with isopropyl alcohol (rubbing alcohol can be used) and rinsed with distilled water between preparation of each composite sample. While filleting the fish, care should be taken not to puncture any of the internal organs. If the body cavity is entered, rinse the fillets with distilled water

Extra Comments Re. Sample Collection:

All fillets for a composite sample can be triple-wrapped in extra heavy duty aluminum foil.
For the whole fish analyses, each fish (CARP) from the composite sample should be individually wrapped in extra heavy duty aluminum foil; the fish should then be bundled together with filament tape.

Amount of Tissue:

400g minimum for each composite sample.

Additional Variables Measured (Fish):

Total length (mm) and weight (g).

Additional Variables Measured (Environmental Health):

None.

Emerging Contaminants Results:

Not considered.

Special Considerations:

Statistical Considerations:

Archives:

None.

Database:

None.

Program Name:	**Regional Ambient Fish Tissue Monitoring Program (continued)**

Pollution Effects:

Dieldrin, chlordane, and PCBs (all of which were banned from use in the United States many years ago) tend to occur at higher levels in bottom-feeding fish such as CARP and CHCT. Mercury is the only contaminant of concern that tends to occur at higher levels in predator fish such as LRBS, SMBS and WALL.

Advantages:

Fairly uncomplicated

Disadvantages:

Focus on human health judging by the effects thresholds used. Difficult to link contaminants in fish to causes: no easily accessible database of information; no other water quality or sediment data collected at the same sites.

Web sites and References:

http://wqm.igsb.uiowa.edu/wqa/raft.html
IDNR 2006
IDNR. 2005
FTN Associates, Ltd and Wenck Associates 2005
http://wqm.igsb.uiowa.edu/wqa/pdf/Raft2001.pdf

Contacts:

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Program Name:	**Cooperative Fish Tissue Monitoring Program: Fish Tissue Environmental Assessment Program**
Official Program Acronym:	None used (Ohio FTEAP)
Region/Locations:	OHIO lakes, rivers and reservoirs

Lead Agency:

Ohio Department of Natural Resources (ODNR) is responsible for monitoring of Inland Lakes, Reservoirs, Lake Eire and parts of Ohio River. Ohio EPA is responsible for monitoring other rivers and complementary parts of the Ohio River.

Years of Data:

The cooperative program started in 1992. Various assessments occur every year.

Frequency of Sampling:

Whenever environmental assessments are required, the only regular fish tissue monitoring being for sport fish on Lake Eire and the Ohio River.

Overall Objectives:

1) Analyze fish fillet and whole body samples to determine the potential for human health and environmental effects;
2) Establish a comprehensive, historical database to evaluate trends in contaminant concentrations, which affect the issuance or removal of human health fish consumption advisories and/or environmental impact assessments; and
3) Identify the extent and magnitude of chemical contaminants in fish to enable anglers to make informed decisions about where to fish and safely consume their catch.

Number of Sampling Sites:

Depends on the assessment program. Usually in large rivers sites are distributed every 9-10 miles and in smaller rivers every 5-7 miles.

Reasons for Choice of Sampling Locations:

In small streams, 3 sampling locations, one at an upstream control location or upstream from an entity/location of concern, a near downstream location and a far downstream location are needed. The final number of stations may be adjusted based upon data requirements. Environmental assessments usually require four stations, the fourth location being a second far downstream location. When the area of concern is located close to a river confluence, the confluence is bracketed with sampling locations upstream and downstream from the confluence. Heavily fished streams have fish tissue sampling stations every 5 miles. A stream location that is visually impacted, or that is known to be receiving chemicals of concern, may be bracketed by additional station locations to evaluate fish tissue chemical uptake.

Contaminants:

Generally metals and organic contaminants (depending on the assessment program).

Effects Thresholds/Source of Guideline:

Environmental assessments: Ohio EPA Division of Environmental Services Fish Tissue (FT) Reporting Limits (RLs)
Sport fish advisories: the FT RLs and US FDA Action Levels
Ohio EPA 2005 State of Ohio Cooperative Fish Tissue Monitoring Program Fish Tissue Environmental Assessment Program. 8pp.
www.epa.state.oh.us/dsw/fishadvisory/FishTissueEnvAssessProg05v2.pdf

Program Name:	**Cooperative Fish Tissue Monitoring Program: Fish Tissue Environmental Assessment Program (continued)**

Fish Species:

In descending order of preference -
For whole body composite samples: CARP, CHCT, Bullheads, Redhorse, Buffalo, WHSC
For skin-off fillet composite samples: CHCT, Bullheads, CARP (Lake Erie), Suckers

Type of Tissue Sample:

Sample collections may involve seven different types of fish tissue samples. Composite samples are preferred.
Mixed Species Whole Body Composites (used only in special situations with prior approval of Ohio EPA)
Skin-off Fillet
Skin-off Fillet Composite
Skin-on Fillet
Skin-on Fillet Composite
Whole Body
Whole Body Composite

Total Sample Size:

Composites: ideally 5 fish (minimum 2) of the same species, with the smallest fish in the sample within 10% of the total length of the largest fish chosen for the sample

Sampling and Handling Methods:

Rinse fish in ambient water. Fish are killed with a blow to the head then weighed and measured (length). Whole Body Composite fish can be wrapped either together or individually in heavy duty aluminum foil and placed in a plastic bag. The skin-on fillet composite sample is prepared by scaling and filleting the fish, wrapping all fillets of composite sample together in heavy duty aluminum foil (making sure the aluminum foil does not get trapped and frozen between folds of tissue) and bagging the sample with appropriate labels. Skin-off fillets are prepared in the same way except the skin is removed. The samples are placed on water ice if they can be put in a freezer the same day, or on dry ice in the case of longer field trips.

Extra Comments Re. Sample Collection:

In special situations, primarily wildlife exposure assessments, Multiple Species Whole Body Composite Sample is used. Multiple-species whole body composite samples of small fish (minnows, etc.) can be used to evaluate wildlife exposure. This is the only occasion when a multiple-species sample is collected and analyzed for an exposure assessment. All of the species in the multi-species sample must be identified. The smallest fish length in the sample must be within 10% of the largest fish length in the sample.

Amount of Tissue:

For all sample types: 150 g minimum to analyze for both metals and organic contaminants.

Additional Variables Measured (Fish):

Fish weight (g) and length (mm).

Additional Variables Measured (Environmental Health):

A wildlife fish tissue environmental assessment must also include the analysis of at least one sediment sample per fish tissue sampling location. A composite surficial sediment sample of from 0 to 3 inches, and no deeper than 6 inches, must be collected. The sediment samples should be analyzed for the Fish Tissue Monitoring Program parameters, or an identified fish tissue chemical(s) of concern, and include sediment analytical results for Total Organic Carbon (TOC) and sediment particle composition.

Program Name:	**Cooperative Fish Tissue Monitoring Program: Fish Tissue Environmental Assessment Program (continued)**

Emerging Contaminants Results:

Not considered

Special Considerations:

Statistical Considerations:

Archives:

None

Database:

None freely available to the public. Internal database at the Ohio EPA used to supply the pollution effects statistics (source - see contact: M. Shaskus)

Pollution Effects:

Ohio's statistics on fish tissue. The data on fillet samples taken from inland lakes, rivers, and Lake Erie for the period 1996-2005: There were approximately 4000 fillet samples analyzed for this data set. For mercury, 87% of the samples exceeded 50 µg/kg. 17% of samples exceeded 220 µg/kg. For PCBs, approximately 22% of the samples exceeded 50 µg/kg. Approximately 8% of the samples exceeded 220 µg/kg.

Advantages:

Targeted sampling is less expensive than regular or random sampling strategies

Disadvantages:

Except for Lake Eire, the monitoring for fish contaminants under this program is a series of environmental assessments conducted as responses to suspected pollution of waters.

Web sites and References:

http://www.epa.state.oh.us/dsw/fishadvisory/index.html
Ohio EPA 2004
www.epa.state.oh.us/dsw/fishadvisory/FishCollectionGuidanceManual05.pdf
Ohio EPA 2005
www.epa.state.oh.us/dsw/fishadvisory/FishTissueEnvAssessProg05v2.pdf
Ohio EPA 2006
http://www.epa.state.oh.us/dsw/fishadvisory/Fish%20Advisory%20Procedure%2007.pdf

Contacts:

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Program Name:	**Washington State Toxics Monitoring Program**
Official Program Acronym:	WSTMP
Region/Locations:	Washington State

Lead Agency:
Washington State Department of Ecology.

Years of Data:
2001 - on-going, presently only the reports for 2002 and 2003 are released.

Frequency of Sampling:
Once per year, in autumn, on a five-year cycle.

Overall Objectives:

- Conduct exploratory monitoring to identify new instances and locations of toxics contamination in freshwater environments;
- Conduct trend monitoring for persistent toxins using residues in edible fish tissue (under development);
- Provide a mechanism to disseminate information to citizens and resource managers about toxics contamination; and
- Develop other toxics monitoring efforts to address particular issues, and establish cooperative programs with other agencies.

Number of Sampling Sites:
2002 exploratory study: 8 sites.
2003 exploratory study: 25 sites.

Reasons for Choice of Sampling Locations:

1. The potential for site contamination.
2. Existence and nature of historical fish tissue or water quality data.
3. Value and interest of the fish resource to consumers.
4. Nature of the fish resource (e.g., species present, management practices).
5. Ability to obtain Scientific Collection Permits from federal and state agencies.
6. Scheduling of the Basin Scoping Process according to Ecology's Watershed Approach to Water Quality which runs on a five-year cycle.

Contaminants:
Mercury, chlorinated pesticides, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/Fs)

Effects Thresholds/Source of Guideline:
Criteria for Protection of Wildlife used:
NAS/NAE 1972 and Newall et al 1987
Human-health-based water quality criteria used:

- **National Toxics Rule (NTR)**. Washington's water quality standards criteria for toxic contaminants were issued to the state in EPA's 1992 National Toxics Rule (NTR) (40CFR131.36). The human-health-based NTR criteria are designed to minimize the risk of effects occurring to humans from chronic (lifetime) exposure to substances through the ingestion of drinking water and consumption of fish obtained from surface waters. They are based on a consumption rate of 6.5 grams/day. The NTR criteria are thresholds that, when exceeded, may lead to regulatory action.
- **Screening Values (SVs)**. The SVs are based on the consumption rate (17.5 grams/day for recreational fishers and 142.4 grams per day for subsistence fishers). Screening

Program Name:	**Washington State Toxics Monitoring Program (continued)**

values for non-carcinogenic effects are calculated using toxicological data from a variety of tests. US EPA. 2000a. http://www.epa.gov/waterscience/fishadvice/volume1.

Fish Species:

KKSL, MNWH, BNTR, CHCT, CTTR, LKWH, LRBS, RBTR, SMBS, WALL, YLPR

Type of Tissue Sample:

Skin-on fillet composites (except for catfish - fillets skin removed).

Total Sample Size:

Between 5 and 10 fish per composite following procedures from US EPA 2000.

Sampling and Handling Methods:

Fish were rinsed in ambient water to remove foreign material from their exterior. Weighed (g) and measured (total length in mm), double-wrapped individually in foil and placed into plastic zip-lock bags. The fish were transported on ice to the laboratory within 72 hrs of collection. At the laboratory the partially frozen fish were grouped into composite samples (similar sized fish of the same species). Scales, spines and otoliths were collected to age the fish. One or two fillets were removed from the fish, depending on the fish size and sample mass required for analysis; fillets from all species included the skin except for catfish where the skin was removed. Fillets were ground and homogenized. Equal amounts of the ground and homogenized tissue from each fillet were combined and homogenized by mixing in a stainless steel bowl, passing this through the grinder once more, then homogenized a final time. Two samples (duplicate) per tissue composite were stored for analysis in -20°C freezer.

Extra Comments Re. Sample Collection:

Amount of Tissue:

2 x 90 g (minimum) of the composite sample.

Additional Variables Measured (Fish):

Total length (mm), total weight (g), otoliths, scales and fin spines removed for aging, body cavity opened to identify sex.

Additional Variables Measured (Environmental Health):

In 2002, stream flow, water temperature, pH, and conductivity were measured in the field. In 2003 total organic carbon (TOC), total suspended solids (TSS), conductivity, pH, and temperature were measured in the field. Integrated water column samples were collected and measured three times from ten sites. The water samples were analyzed for 115 chlorinated, organophosphorus, and nitrogen pesticides.

Emerging Contaminants Results:

Flame retardants (PBDEs) detected in fish tissues but not exceeded any of the thresholds.

Special Considerations:

Statistical Considerations:

Archives:

Extra tissue homogenate (composite) was archived

Program Name:	**Washington State Toxics Monitoring Program (continued)**

Database:

Environmental Information Management System
EIM database - on line, searchable
http://www.ecy.wa.gov/services/as/iip/eim/index.html

Pollution Effects:

Levels of PCBs and PCDD/Fs in fish tissue frequently exceeded criteria for the protection of human health, while levels of DDT, dieldrin, and mercury showed fewer exceedances. Other contaminants detected in fish tissue were chlordane compounds, hexachlorobenzene, pentachloroanisole, methoxychlor, and PBDEs. In 2003, six contaminants exceeded the NTR criteria and/or EPA screening values in fish tissue:

- Total PCBs in eight samples – both NTR criteria and EPA screening values.
- PCDD/Fs in seven samples – both NTR criteria and EPA screening values.
- Dieldrin in two samples – both NTR criteria and EPA screening values.
- 4,4'-DDE in one sample – NTR criteria.
- Total DDTs in six samples – EPA screening values.
- Mercury in 12 samples – EPA screening values. Criteria for the protection of wildlife were not exceeded in any of the tissue samples. Water Quality: six pesticides were detected at low levels and low frequencies: bromacil, dichlobenil, atrazine, diuron, hexazinone, and terbacil.

Advantages:

Comprehensive list of chemicals analyzed

Disadvantages:

Small number of sites

Web sites and References:

http://www.ecy.wa.gov/programs/eap/toxics/index.html
Seiders and Kinney 2004
http://www.ecy.wa.gov/biblio/0403040.html
US EPA 2000
http://www.epa.gov/ost/fishadvice/volume1

Contacts:

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APPENDIX 3

LIST OF CONTAMINANTS FROM ALBERTA FISH TISSUE CONTAMINANT STUDIES

Metals

Aluminium (Al)
Antimony (Sb)
Arsenic (As)
Barium (Ba)
Beryllium (Be)
Boron (B)
Calcium (Ca)
Cadmium (Cd)
Chromium (Cr)
Cobalt (Co)
Copper (Cu)
Iron (Fe)
Lead (Pb)
Lithium (Li)
Magnesium (Mg)
Manganese (Mn)
Mercury (Hg) Total, Organic and Inorganic
Molybdenum (Mo)
Nickel (Ni)
Phosphorous (P)
Potassium (K)
Selenium (Se)
Silicon (Si)
Silver (Ag)
Sodium (Na)
Strontium (Sr)
Titanium (Ti)
Thallium (Tl)
Tin (Sn)
Uranium (U)
Vanadium (V)
Zinc (Zn)
Zirconium (Zr)

PAHs

anthracene
acenaphthene
acenaphthylene
benzo(a)anthracene/chrysene
benzo(b&k)fluoranthene
benzo(g,h,i)perylene
benzo(a)pyrene
biphenyl
dibenzo(a,h)anthracene
fluoranthene
fluorene
indeno(c,d-123)pyrene
methyl napthalene
naphthalene
phenanthrene/anthacene
pyrene

Alkylated PAHs

C1 substituted acenaphthene
C1 substituted benzo(a)anthracene/chrysene
C2 substituted benzo(a)anthracene/chrysene
C1 substituted biphenyl
C2 substituted biphenyl
C1 substituted benzo(b or k) fluoranthene/methyl benzo(a)pyrene
C2 substituted benzo(b or k)fluoranthene/benzo(a)pyrene
C1 substituted dibenzothiophene
C2 substituted dibenzothiophene
C3 substituted dibenzothiophene
C4 substituted dibenzothiophene
C1 substituted fluoranthene/pyrene
C1 substituted fluorene
C2 substituted fluorene
C1 substituted naphthalenes
C2 substituted naphthalenes
C3 substituted naphthalenes

C4 substituted naphthalenes

C1 substituted phenanthrene/anthracene

C2 substituted phenanthrene/anthracene

C3 substituted phenanthrene/anthracene

C4 substituted phenanthrene/anthracene

1-methyl-7-isopropyl-phenanthrene (retene)

Dioxins

∑Dioxins

PCDDs (2,3,7,8-TCDD)

Total TCDD

Total PCDD

Total H6CDD

Total H7CDD

OCDD

Plus other congeners

Furans

∑Furans

PCDFs (2,3,7,8-TCDF)

Total TCDF

Total PCDF

Total H6CDF

Total H7CDF

OCDF

Plus other congeners

Polychlorinated Biphenols (PCBs)

Aroclor 1248, 1254, 1260, 1242

1,2 Dichlorobenzene

1,3 Dichlorobenzene

1,4 Dichlorobenzene

1,2,4 Trichlorobenzene

Hexachlorobenzene

∑PCB

Other Organic Compounds

1,3,5-tribmethylbenzene

2-methylthiophene

2,3,5-trimethylnaphthalene

2, 4-D; 2, 4, 5-T; Picloram

2,5-dimethylphenol

2,6-dimethylnaphthalene

α-endo-sulfan

Aldrin

anisole/veratroles

benzothiophene

Chlordane (cis)

∑CHL (total chlordane related compounds)

Chorinated phenolics

Chlorophenolics

Daconil

∑DDT

RP1 DDT

p,p1-DDD

p,p1-DDE

Diazinon

dibenzothiophene

Dicamba

Dicosol

Dieldrin

Dioxythion

Dursban

Endosulfan

Endrin

EPN (0-ethyl, 0-4-nitro-phenyl phenyl phosphono-thiolate)

Ethion

HCB (tetra-, penta- and hexachlorobenzene)

γ, β, α HCH (hexachlorocyclohexane, or BHC)

∑HCH (total hexachlorocyclohexanes)

Heptachlor

Heptachlor epoxide

Lindane

m+p-xylenes

Malathion

MCPA (metacholorphenoxy acetic acid)

MCPB (metachlorophenoxy butyric acid)

mesitylene

Methoxychlor

MEO-DDE

MEO-DDT

Mirex

Organochlorine pesticides

Oxychlordane

o-xylene

Parathion

PCNB (Pentachloronitrobenzene)

Pentachlorobenzene

Pentachlorophenol

Perthane

phenol

Polybrominated Biphenyls

RFAs (Resins and Fatty Acids)

Silvex

Sumithion

Tedion

Telodrine

TCNB (Tetrachloronitrobenzene)

Thiodan I

Thiophene

Toluene

total cresols

Toxaphene

APPENDIX 4

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